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Causes of Deficiency of Soybean Flour as a Pollen Substitute for Honeybees[1]

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Soybean flour is used as an ingredient for preparing pollen substitutes or pollen supplements for feeding colonies of bees when the latter lack adequate amounts of pollen—the main source of protein, lipids, minerals and vitamins in the nutrition of the bees.

Although soybean flour when fed alone is adequate for rearing brood (Haydak, 1940, Haydak & Tanquary 1942) the amount of brood reared is considerably below that reared when dried skim milk or dried brewers' yeast is added to the soybean flour. It has been pointed out that the heat-treated soybean flour is an excellent source of protein of a high biological value and that its mineral and fat contents are high enough to justify the assumption that those constituents are supplied in amounts sufficient for the proper development of bees. The same cannot be said of the vitamins present in soybean flour, which is rather low in riboflavin. Its niacin (nicotinic acid) content is also considerably below that of either pollen or the dried brewers' yeast (Haydak 1945).

It is known (Fraenkel 1943) that both riboflavin and niacin are indispensable for the normal growth and development of insects. In order to ascertain whether the insufficiency of these two vitamins plays an important role in the inadequacy of soybean flour alone as food for bees or whether a lack of some other factors is contributing to this deficiency, experiments were undertaken in the summers of 1947 (preliminary) and 1948.

Experimental colonies were formed using bees which had never eaten pollen (not over 10 hours old). They were hived on pollen free combs placed in three-frame nuclei located in isolated cages. A paste made of 70 gm. soybean flour, 400 gm. honey, 20 cc. ethyl alcohol and 20 cc. water was placed in cells of the combs given to the control colonies. For the positive controls 70 gm. soybean flour-dried brewers' yeast mixture (4:1) was used. To ascertain the value of vitamin supplementation pure soybean flour was fortified with 40 mg. riboflavin, 100 mg. niacin, or with a mixture of 40 mg. riboflavin and 100 mg. niacin and thus fortified foods were given to the respective experimental colonies.

The vitamins were dissolved in the alcohol-water mixture and the solution was incorporated into the food. The resulting paste was distributed to the cells of the combs by means of a spatula. Two colonies were used for testing each food.

The bees were weighed before being added to the nuclei. On an average, there were 8.61 bees per gram. A good laying queen was introduced in each of the colonies. On the fifth day water was given and the pollen substitute candy was placed directly over the frames of the nucleus.

The candy was made by mixing 70 gm. of dry food, 170 gm. honey, 10 cc. of ethyl alcohol and 15 cc. of water. The vitamins were dissolved in the alcohol-water mixture which was incorporated into the candy. Two control colonies received pure soybean flour candy. The other two were offered soybean flour-dried brewers' yeast mixture (4:1). Each other group of two experimental colonies was given the pure soybean flour candy with an addition of 20 milligrams of riboflavin, 50 mg. of niacin, or a mixture of

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20 mg. riboflavin and 50 mg. niacin, respectively.

From the seventh day on sugar solution was supplied to all colonies *ad libitum*. On the seventh day the dead bees were counted in each colony, and discarded. This was done because the mortality of young bees during the first few days after hiving may be due to various causes irrespective of food (Haydak 1933). However, the weight of the dead bees was calculated and approximately equal weight of new emerged bees was added to make the colonies of about equal strength at the beginning of the actual test. After that the dead bees were removed and counted more often. For computation of mortality only those that died during the first 10 days of the test were taken into consideration.

For ascertaining the brood rearing activity of the colonies, the latter were examined daily. After the first sealed brood was noted, the bees were examined only to ascertain the presence of the queen. Ten days later both sealed and unsealed brood was counted. Such counts, for each colony, were repeated in three more 10-day intervals. The weight of the food consumed by the bees was recorded throughout the experiment. The results of the preliminary experiments are presented in table 1, those of 1948 experiments in table 2.

From table 2 it is evident that mortality rate in all cases did not differ appreciably. All colonies reared brood. However, the character of the brood rearing was different.

On examining the amount of sealed brood at the end of the first 10-day period, it is seen that the lowest count was in the colonies supplied either riboflavin or niacin alone, the highest in those in which soybean flour was supplemented with both of the vitamins or with dried brewers' yeast. However, the character of the open brood at the end of the first period was distinctly different in the colonies fed soybean flour alone and those offered the fortified foods. While the colonies fed soybean flour alone had the larvae mostly 3.5 days old and there were very few older larvae present, the colonies supplied with vitamins or yeast had all brood stages well represented, although in the colonies receiving single vitamins the brood was somewhat scattered.

In the second and following periods the age differences of the open brood were still more obvious. As time progressed, the numbers of the sealed brood cells in the colonies fed soybean flour alone or fortified with riboflavin were markedly diminishing while in those supplemented with niacin this decrease was more gradual. The slowest decrease was in the colonies fed either both vitamins or dried brewers' yeast in addition to soybean flour. These differences in the character of the brood rearing are still more obvious when one compares the number of sealed cells at the end of each period with the number of unsealed larvae at the end of the preceding period (Table 3).

It is obvious that the rate of normal brood rearing in the colonies fed soybean flour alone or supplemented with riboflavin in the third period abruptly decreased while in the colonies fed soybean flour supplemented with niacin, both riboflavin and niacin or the dried brewers' yeast the rate of the normal brood rearing started to diminish gradually and by the end of the fourth period still a considerable percentage of larvae reached maturity and were sealed. This means that while a relatively normal brood rearing continued uninterruptedly throughout the whole four periods in the colonies in which soybean flour was supplemented with niacin, riboflavin and niacin, or with dried brewers' yeast, the brood rearing in the colonies fed soybean flour alone or supplemented with riboflavin was impaired since only a small percentage of larvae reared during the third and fourth periods reached maturity and was sealed.

This behavior could be explained by a supposition that the young bees fed deficient diets at the beginning used the dispensable part of the vitamins stored in their bodies to supplement the larval food. It is known that nurse bees are able to use materials stored in their bodies for rearing brood (Haydak 1935). Haydak & Vivino (1943) found that the concentration of the B vitamins in the whole bees is higher than the values reported for other insects. As long as there was a physiological possibility of using those stored vitamins they were presumably used; when they were no more available, the brood rearing dropped off abruptly. This is reflected in the total number of sealed cells produced in those colonies (Table 4).

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Table 1.—General results. Feeding experiments of 1947.

Food	Strength of Colonies	Brood Rearing Activity in Periods I Sealed cells	I Unsealed larvae	II Sealed cells	II Unsealed larvae	III Sealed cells	III Unsealed larvae	Total Sealed Cells	Indices of the Food Efficiency Periods I	II	III	Total	Candy Consumed for Rearing One Bee
	gm.	No.	No.	No.	No.	No.	No.	No.					gm.
Soybean flour (SBF)	822	1855	453	197	580	3	327						
	873	1939	507	328	621	0	476						
Ave.	848	1897	480	263	601	2	402	2161	1.2	1.0	1.0	3.2	.22
SBF+ riboflavin	812	2007	476	281	895	10	444						
	867	1011	1099	288	1427	112	588						
Ave.	840	1509	738	285	1161	61	516	1855	1.0	1.1	30.5	32.6	.25
SBF+ riboflavin +niacin	816	1744	448	481	541	298	405						
	866	1821	737	504	407	210	227						
Ave.	841	1783	543	493	474	254	316	2529	1.2	1.9	127.0	130.1	.16
SBF+ dried yeast	839	2010	573	439	794	497	463	2946	1.3	1.7	249.0	252.0	.16

The number of sealed cells is the most important because it represents the number of larvae reaching maturity and resulting in emerged bees.

In order to find out what influence, if any, the number of adult bees present in the colonies at the beginning of each period had on the amount of young bees produced in this period, the strength of each colony at the beginning of each 10-day period was established by subtracting the number of dead bees from the original number of bees used in establishing the nucleus and adding to it the number of the young bees produced by the colony during the previous period (number of sealed cells).

From table 2 it is evident that the differences were not so marked as to influence the outcome. Since young bees normally perform nursing duties in outside colonies, the number of young bees added through the brood rearing in the experimental colonies could have been, to a great extent, instrumental in influencing the difference in the type of brood rearing, especially because the number of the young bees reared by all colonies during the first two periods differed (Table 4). However, when we compare the character of the brood rearing (Table 3) in the riboflavin or niacin fortified colonies, which produced about the same number of sealed cells (2025 and 2073 respectively) with the type of brood rearing in the niacin and niacin plus riboflavin supplemented colonies, where this difference was considerable (2073 and 2457 respectively), then we can infer that such influence was probably quite small.

It has been demonstrated (Lotmar 1930) that *Nosema* infection interferes with the development of the pharyngeal glands. However, periodical examinations of dead bees in all colonies did not show even traces of infection throughout the duration of the experiment. Therefore, those differences in brood rearing activity cannot be explained by the influence of that disease.

Probably the difference in the vitamin content of the foods supplied to the colonies played the most important role in the results obtained (Table 5). The amount of vitamins added to the diet was so calculated that the content would not be smaller than that present in pollen. According to Vivino & Palmer (1944), pollen collected by the bees at the University apiary had about 18 micrograms of riboflavin and 200 micrograms of niacin per gram of fresh matter. The amount of riboflavin present in the experimental foods was considerably greater, namely 76 micrograms per gram. This was done on purpose, in order to compensate for a possible loss of this vitamin during preparation of the food and while feeding the cakes to the bees (the experimental cages were located in a lighted laboratory and although the food was covered with a black waterproof paper there was a possibility of loss). The amount of niacin was equal to 198 micrograms per gram of fresh food—about equal to that found in pollen. However, the food that produced

Table 2.—General results. Feeding experiments of 1948.

Food	Grams per Colony	Dead Bees (Grams)	Mortality Per Cent	Brood Rearing Activity in Periods							
				I		II		III		IV	
				Sealed Cells	Un-sealed Larvae	Sealed Cells	Un-sealed Larvae	Sealed Cells	Un-sealed Larvae	Sealed Cells	Un-sealed Larvae
Soybean flour	842	33		1848	1016	730	546	32	711	1	447
	854	86		1466	276	182	860	129	459	3	333
Ave.	848	60	7.1	1657	646	456	703	80	585	2	390
Soybean flour+ riboflavin	856	49		1946	957	485	854	14	810	0	446
	846	90		1045	586	572	998	145	410	0	246
Ave.	851	70	8.2	1496	772	529	926	80	610	0	346
Soybean flour+ niacin	861	30		2032	730	529	758	368	888	325	240
	854	112		865	537	718	586	345	191	28	163
Ave.	858	71	8.3	1449	634	624	672	357	540	177	202
Soybean flour+ riboflavin+ niacin	845	37		1932	967	581	591	388	598	262	337
	848	83		1877	839	523	1074	574	548	210	428
Ave.	847	60	7.1	1905	903	552	833	481	573	236	383
Soybean flour+ dried yeast	847	44		2288	783	605	986	594	932	270	379
	852	63		2091	478	760	517	531	541	345	401
Ave.	850	53	6.2	2190	631	683	752	563	737	308	390

Food	Strength of the Colonies at the Beginning of Periods in Grams			Indices of Food Efficiency Periods					Candy Consumed From Rearing One Bee
	II	III	IV	I	II	III	IV	Total	
Soybean flour	1024	1012	747						
	938	796	657						
Ave.	981	904	702	1.1	1.0	1.0	1.0	4.1	.31
Soybean flour+ riboflavin	1033	993	750						
	878	756	554						
Ave.	956	875	652	1.0	1.1	1.0	0	3.1	.32
Soybean flour+ niacin	1067	1031	777						
	843	729	588						
Ave.	955	880	896	1.0	1.3	4.5	88.0	94.8	.27
Soybean flour+ riboflavin+ niacin	1033	952	736						
	983	840	700						
Ave.	1008	896	718	1.3	1.2	6.0	118.0	126.5	.25
Soybean flour+ dried yeast	1069	906	800						
	1032	932	774						
Ave.	1050	919	787	1.5	1.5	8.0	154.0	164.0	.25

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Table 3.—Character of brood rearing. (Sealed brood cells percentages of the number of unsealed larvae in each of the previous periods.)

Food	The End of Periods		
	II	III	IV
	per cent	per cent	per cent
Soy bean flour			
1947	55.0	.3	—
1948	70.5	11.3	.3
Soy bean flour+ Riboflavin			
1947	38.0	5.2	—
1948	68.5	8.6	0
Soy bean flour+ Niacin			
1948	98.4	53.1	32.8
Soy bean flour+ riboflavin+ Niacin			
1947	90.8	53.6	—
1948	61.1	57.7	41.5
Soy bean flour+ Dried yeast			
1947	76.6	62.6	—
1948	108.2	74.9	41.8

the best results was the one containing dried brewers' yeast; this mixture had concentrations of only 5 micrograms of riboflavin and 40 micrograms niacin per gram.

It is apparent that niacin is the main limiting factor in soybean flour. However, the riboflavin content of the latter is very low and an addition of this vitamin to the diet improved the quality of the food still further. On the other hand, an addition of dried brewers' yeast produced still better results. This is true both for the preliminary and the subsequent experiments (Tables 1 and 2). Apparently there is some other factor or factors in which soybean flour is deficient and which are supplied by dried brewers' yeast.

The indices of food efficiency were obtained by assigning one point to the food giving the lowest average brood production in each category (sealed cells) and dividing by this lowest average the averages of the brood counts in the colonies supplied with other foods. The sum of the points for all periods gave the total index of food efficiency.

Table 4.—Total average brood rearing activity of the colonies used in 1948 experiments.

Food	Sealed Cells	Unsealed Cells	Total	Index of Food Efficiency	Total Sealed at the Beginning of III Period
	No.	No.	No.		No.
Soybean flour	2195	2324	4519	1.0	2113
Soybean flour+ riboflavin	2105	2654	4759	1.0	2025
Soybean flour+ niacin	2607	2048	4665	1.2	2073
Soybean flour + riboflavin+niacin	3174	2692	5866	1.5	2457
Soybean flour+ dried yeast	3744	2510	6254	1.8	2873

Table 5.—Riboflavin and niacin content of candy (micrograms per gram of fresh matter).

Candy	Riboflavin	Niacin
Soy bean flour	.8	9
Soy bean flour+riboflavin	76.0	9
Soy bean flour+niacin	.8	198
Soy bean flour+riboflavin +niacin	76.0	198
Soy bean flour+dried yeast	5.0	40

Since the record of the food consumption was kept there is a possibility of computing roughly an approximate amount of nitrogen used for the rearing of one bee (Table 6). The protein content of the soybean flour used in the experiment was equal to 50 per cent, that of dried brewers' yeast was also 50 per cent. Taking this as a basis the total amount of protein consumed by each group was computed. The nitrogen content of bees reared on soybean flour was found to be equal to 1.96 mg. per bee (Haydak, 1937). When the quantity of N contained in reared bees is substracted from the amount consumed by each group, then the amount of N used for the development and metabolism of original bees and of those that were produced by the experimental colonies (equal to the number of sealed cells, except those counted at the end of the fourth period) could be obtained. Haydak (1934) found that the average N content of fully developed (6 to 20 days old) bees, with the digestive tracts removed is equal to 2.50 mg. The average N content of emerging bees is equal to 1.98 mg. of which 0.24 mg. is for the digestive tract. The latter value could be accepted as the N content of digesitve tracts free of pollen for all ages of bees, because the digestive tracts of bees 31 days old, which are also almost free of pollen contain 0.25 mg. N. The N content of the whole bees, 6 to 20 days old, is then equal to about 2.74 mg. Therefore the increase in the N content of fully developed over emerging bees is equal to 0.76 mg. By subtracting this value from the total amount of N used

by the adult bee one can obtain the amount of N used by each adult bee in catabolism and the synthesis of the larval food. Thus the amount of N used by the adult bees in catabolism and synthesis of the larval food for rearing one bee can easily be calculated. Adding to this number the amount of N content of an emerged bee reared in experimental colonies, the total approximate amount of N used in the rearing of one bee can be ascertained. It is interesting to note that the numbers for the colonies having about normal brood rearing are almost equal to the numbers given by Alfonsus (1933), who fed colonies made of adult developed bees, a weighed quantity of pollen and ascertained that for rearing one bee the nurse bees used 144.9 mg. of pollen, which is equal to 4.67 mg. N. The number given by Haydak (1935) is smaller (3.21 mg.). However, the latter value was calculated from the results obtained from a colony fed only sugar solution, the bees of which used their stored protein reserves for the production of the larval food. There was no waste in the digestive processes. From tables 1, 2, and 6 it is also obvious that more protein was used for the rearing of one bee in those colonies that were fed deficient foods. It appears that the amount of N used in rearing one bee is inversely correlated with the index of food efficiency (Tables 2 and 6).

SUMMARY.—Colonies consisting of newly emerged bees which have never eaten pollen were kept in isolated cages and fed candy made of soybean flour alone and that fortified with riboflavin, niacin, both riboflavin and niacin, and dried brewers' yeast. The mortality of bees was noted. The brood rearing activity was followed for four consecutive 10-day periods.

All colonies reared brood. However, in the colonies fed soybean flour alone or soybean flour fortified with only riboflavin there was an abrupt impairment in the brood rearing activity beginning with the third period. The decrease in the brood rearing activity in the colonies fed soybean flour supplemented with niacin was more gradual. The brood rearing activity in the colonies offered soybean flour fortified with both niacin and riboflavin or dried brewers yeast, although gradually decreasing, was the closest to the normal brood rearing. The best results were obtained in the colonies, the food of which was fortified with 20 per cent of dry brewers' yeast.

The results indicated that niacin probably is the main limiting factor in soybean flour. The amount of riboflavin in the latter is also inadequate since an addition of riboflavin to the niacin-fortified diet increased the nutritive value of the food still further. There seem to be some other factors in which soybean flour is deficient and which are supplied by dried brewers' yeast.

The calculated amount of nitrogen used

Table 6.—Quantity of Protein N used by the experimental colonies.

Food	Number of Bees	Protein	Nitrogen	Nitrogen					
				Contained in Reared Bees	Used for Development & Metabolism of Adults		Spent in Catabolism & Synthesis of Larval Food		
					Total	Per Bee	Per Adult Bee	Per Reared Bee	Used in Rearing One Bee
		gm	mg	mg	mg	mg	mg	mg	mg
Soy bean flour	9488	124.76	19962	4202	15760	1.66	.90	3.4	5.36
Soy bean flour+ Riboflavin	9329	124.23	19877	4126	15751	1.70	.94	4.2	6.16
Soy bean flour+ Niacin	9809	126.74	20278	5110	15168	1.55	.79	3.0	4.96
Soy bean flour+ Riboflavin+ Niacin	10222	140.73	22517	6221	16296	1.60	.84	2.7	4.66
Soy bean flour+ Dried yeast	10746	156.57	25061	7338	17723	1.60	.84	2.4	4.36

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in rearing one bee was equal to 4.96, 4.66, and 4.36 mg. for the colonies fortified with niacin, both niacin and riboflavin and dried brewers' yeast respectively. That amount in the colonies fed soybean flour alone or that supplemented with riboflavin was greater, being 5.36 and 6.16 mg. respectively. It appears that the amount of N used in rearing one bee is inversely correlated with the index of food efficiency.

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Time of Evaluation and the Dosage-Response Curve

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In comparing insecticides, the validity of the comparison is dependent upon the precision with which each insecticide is characterized in equivalent terms. Apart from the physical factors entering into the insecticidal formulation and details of testing, both the killing dose and the time required to kill are important features in the performance of the chemical compound. These characteristics are seldom considered together, and by this neglect, comparisons lose in value as will be seen in the following discussion.

Killing dose and time required to kill are not mutually exclusive. A low dose of a toxicant acting for a long time may be as effective as a high dose acting for a short time. Too often, however, experimental design is based on the assumption that these two factors act independently. When the killing dose of a chemical is expressed in terms of mortality resulting from the application of certain dosages or concentrations (dosage-mortality studies), the time required to kill is likely to be ignored. On the other hand, the survival time-mortality studies, in which mortality counts are made at intervals after treatment, do not take into account the effects of dosage other than the experimental requirement that an "effective" dosage be used. This technique more properly defines the speed of action, although some investigators have used it as a measure of over-all toxicity. The time required to kill cannot be divorced from the duration of exposure to the toxicant, which is likely to be one of three degrees depending upon the experimental design. When a single application of a toxicant is made to insects, as for example by injection or by spraying, the dose applied can only remain the same or decrease due too evaporation, mechanical removal, or physiologic elimination. On the other hand, when insects are exposed to a toxicant in a vapor or liquid state for different periods of time and then removed from the toxic medium, there is an opportunity for a cumulative dose until the time of removal. Physiologic elimination may tend to offset this, but usually

the duration of exposure is short enough that elimination is not likely to be an important factor until the period of exposure is over.[1] An extension of this condition exists when insects are kept in a toxic medium until death, as for example when mosquito larvae are kept in water treated with a toxicant until they succumb or when grain beetles are reared in poisoned media and mortality is noted at definite intervals of time. In this case, certainly, the duration of exposure and the time required to kill are confounded. In the following discussion, the time of evaluation represents the time required to kill insofar as it is based upon mortality counts made at intervals after application of single dosages by injection.

In the course of experimental work involving the application of several toxicants to four species of insects by various routes of administration (Beard, 1949) one test involving three replicates gave peculiar results. This test involved known dosages of parathion dissolved in olive oil injected into the alimentary tract of Japanese beetle grubs (*Popillia japonica* Newm.). As illustrated in figure 1,[2] the response in terms of mortality two days after treatment did not follow a rectilinear

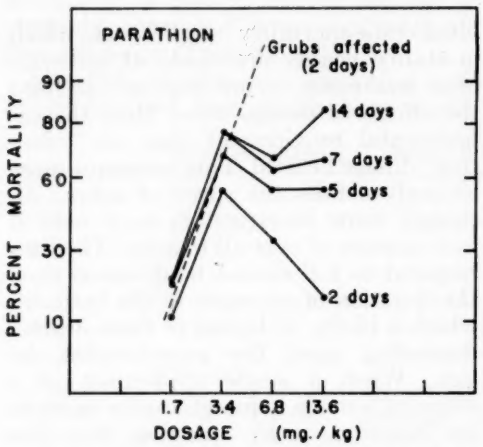

FIG. 1.—Dosage-mortality curves (solid lines) of Japanese beetle grubs injected enterally with parathion. Curves are based on evaluations made at different times after treatment.

relationship when plotted on logarithmic probability paper, although response in terms of individuals affected did so. Instead, with increasing dosage, mortality increased to a point and then decreased. Evaluations made 5, 7, and 14 days after treatment, however, resulted in a tendency for the curve to straighten and approach the simple dosage-response curve. In this case, then, if (as would be unlikely) evaluation had been made only after 14 days, the compound nature of the curve could have been overlooked, and if evaluation had been made only after 2 days, the data, without further explanation, might have been discarded as being too poor to consider. The explanation is a simple one. The appearance of the grubs made it obvious that the higher dosages had a purgative action which must have been rapid enough to eliminate the toxicant in lethal concentrations. But the purgative action was so violent that death resulted in many cases although at a slower rate than when due to the direct action of the toxicant. Some recovery prevented the final mortality curve from coinciding with the curve for individuals affected. In this case increase in the time of evaluation tended to simplify the compound curve only by obscuring what had taken place. It may be that the compound nature of dosage-response curves for other toxicants has been overlooked because evaluations have not been made at sufficiently frequent intervals of time as well as by not using dosages in small enough increments.

Hansberry & Chiu (1940), in a study of *Tribolium confusum* reared in flour containing calcium arsenate, published mortality data which, when plotted, show a striking similarity to those illustrated above. These authors concluded that the higher concentrations acted as a repellent so that the beetles would not feed until starved to it. In this case, too, the increased time of evaluation tended to simplify the compound curve. Dimond *et al.* (1941), Turner (1945), Yeager & Munson (1945), and Munson & Yeager (1945) have published compound dosage-response curves of different types. It may be that these curves are basically similar in that at certain points the dosages administered are not the same as the doses of the unmodified toxicant actually present or available to act at the site of action. Of

[1] Bliss (1940) has discussed the relationship between concentration, time of exposure, and effect, and has illustrated methods of analyzing these variables.

[2] In this and all subsequent illustrations dosage and/or time of evaluation are represented on a logarithmic scale, and mortality is represented on a probit scale.

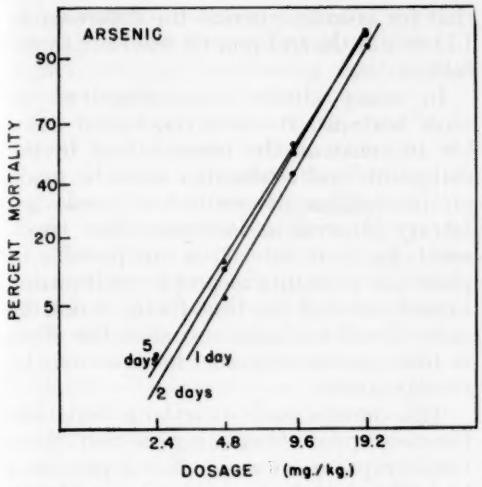

FIG. 2.—Dosage-mortality curves of milkweed bugs injected parenterally with arsenic (sodium metarsenite). Curves are based on evaluations made at different times after treatment.

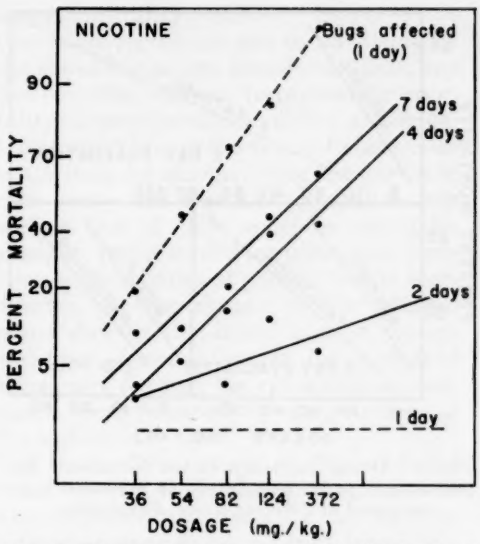

FIG. 3.—Dosage-mortality curves (solid lines) of milkweed bugs treated topically with nicotine. Curves are based on evaluations made at different times after treatment.

course the reasons for this coming about may be quite different in the several cases.

Among a series of simple dosage response curves, several were selected for discussion. These are all based upon the application of the toxicant to adult milkweed bugs, *Oncopeltus fasciatus* (Dall.).

Figure 2 illustrates that arsenic, in the form of sodium metarsenite, injected into the body cavity of milkweed bugs yielded dosage-response curves which did not change appreciably either in position or slope within the limits of time consistent with usual evaluation intervals. This would be expected with a fast killing compound.[1]

With a variety of other data, the dosage response curve shifted with the time of evaluation. As an example, the data derived from the topical application of measured drops of nicotine (free base) to the milkweed bug are represented by calculated curves in figure 3. After 24 hours a good fitting dosage-response curve was obtained from those individuals paralyzed or otherwise affected. Since many of those affected might recover, mortality was considered to include only those dead beyond doubt. After 24 hours, however, too few bugs fell into this category to make possible the calculation of a curve. After 2 days, sufficient bugs died to indicate a response to increasing dosage, and thereafter evaluations produced a steepening of the curve and a shift to the left until the end-point was reached when all of the affected individuals had either recovered or died. This type of change in the dosage-response curve has been encountered frequently.

Another type of change which might be encountered is one in which the slope flattens because of a pivoting about the upper region of the curve. No comparable data are at hand to demonstrate this, although fragmentary data have suggested it. In these cases it may be due to the artifact of having data only at the upper levels of the curve rather than the full range, but a flattening of the slope with time of evaluation would be expected if the higher dosages of a toxicant killed quickly and the lower dosages were not eliminated and killed more slowly.

The importance of these changes becomes apparent when the curves for two compounds are compared at different time intervals. In Figure 4, curves for arsenic and parathion, injected into the body cavity of milkweed bugs, are shown. The end-point of the observations was considered to be when all affected individuals either died or recovered. This was five days for arsenic and six days for parathion. At the end-points, the two dosage-

[1] Even these data were not taken in such a way as to detect the compound nature of the curve for arsenic demonstrated by Yeager and Munson.

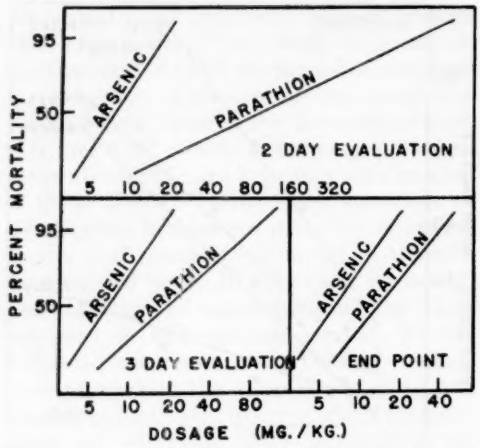

FIG. 4.—Dosage-mortality curves for arsenic and parathion, injected parenterally in milkweed bugs, compared at different times of evaluation.

response curves are not too far from being parallel, and the LD-50 for parathion is only about twice that for arsenic. If the evaluation had been made only after 2 days, the differences in slope and position would have been much greater. In this comparison the LD-50 for parathion is about 14 times that of arsenic and because of the difference in slope, the LD-95 for parathion would be almost 250 times that for arsenic, whereas the difference in LD-95's at the end-point is less than threefold.

In many studies comparing two or more toxicants it is not considered feasible to continue the observations to the end-point, and evaluation must be made on mortalities determined at some arbitrary interval or intervals after treatment. In these cases it is not possible to place the toxicants in proper relationship to each other if the time factor is not the same for all toxicants or unless the effect of time can be estimated in some way by extrapolation.

This time factor is something more than the mere speed of toxicologic action. Nicotine is rapid in its action but it permits a high degree of recovery. Some of the newer insecticides are slower in action but permit little or no recovery. In both cases, however, the position and slope of the dosage-response curves may change with time in the same way but differ from the curve of a fast acting chemical which permits no recovery. Also, as manifested by compound curves, other physiologic phenomena may be involved. In studying new compounds as candidate insecticides, these aspects are not known and without

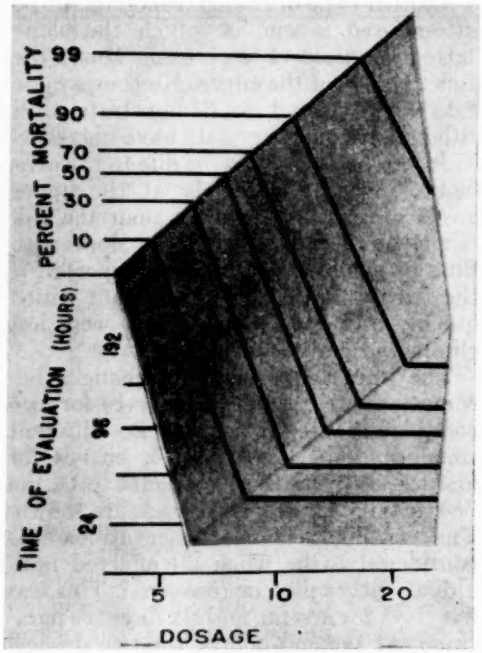

FIG. 5.—Photograph of a three-dimensional model illustrating response of milkweed bugs injected parenterally with arsenic.

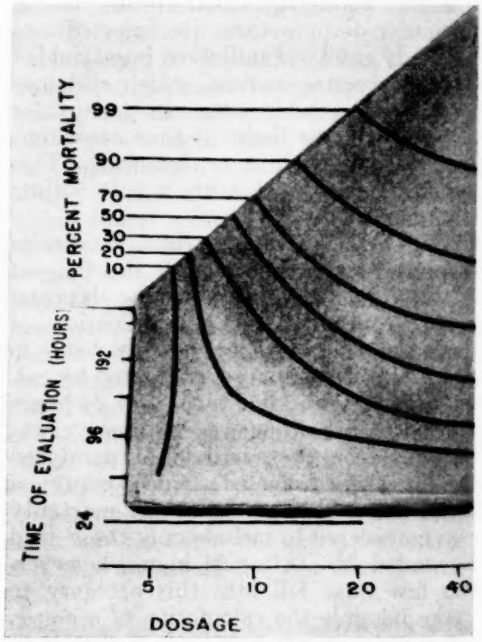

FIG. 6.—Photograph of a three-dimensional model illustrating response of milkweed bugs injected parenterally with parathion.

an evaluation of them, potentially good insecticides may be overlooked, or in comparative studies, misleading conclusions may be drawn.

The dosage-response curve has provided a good tool for evaluating toxicants in terms of dosages required to effect equal control at given levels (Bliss 1935). Thus LD-50 has become a standard of expression, but this may be based on any arbitrary time of evaluation as well as the end-point. The survival time-mortality curve makes it possible to estimate the time at which any given percentage of individuals will succumb to a toxicant (Bliss 1937), but at only one dosage level. There is not available a convenient three-dimensional yardstick to interrelate dosage, mortality, and time of response. There are several methods of indicating these values graphically, among which are the three dimensional model, the topographic chart, and the nomogram or alignment chart.

Three dimensional models have been published for a wide variety of variables, but most pertinent to this discussion are those of Hansberry and Chiu. These models were constructed of wood and based upon the actual experimental data. Figures 5 and 6 are retouched photographs of plaster models constructed from the calculated data illustrated in figure 4. These represent, in effect, a series of survival time-mortality curves in planes at right angles to the planes of a series of dosage-mortality curves. Since these curves are rectilinear due to the fitting by the use of log-probit transformations, any line on the surface (representing mortality) drawn parallel to either coordinate is a straight line in the vertical plane. And in the data for arsenic, since the curves in each series are essentially parallel, any surface line of this model is essentially straight. In the model for parathion, however, surface lines not parallel to the coordinates are curvilinear in the vertical plane due to the interaction of dosage and time of evaluation. In the models of Hansberry & Chiu, the experimental variations were reflected by irregularities of the surfaces.

If the models pictured in Figures 5 and 6 are viewed from above, the isometric lines representing mortality can be considered contour lines and transferred to a two-dimensional topographic chart (Figures 7 and 8). This is essentially the treatment given by Richardson & Haas (1932) in comparing pyridine and nicotine, although they used only one isometric line—the 50 per cent mortality level—and considered time as a dosage factor rather than as a response factor. For the data being discussed, this method of illustration is shown in Figure 9. This has the advantage of making possible the presentation of values for more than one toxi-

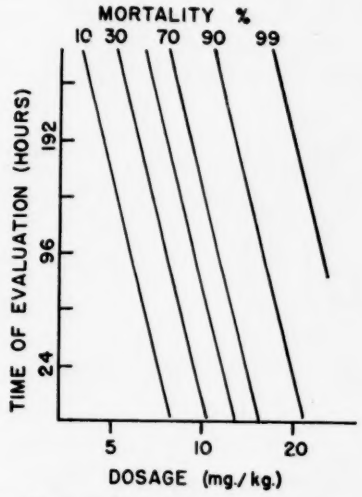

FIG. 7.—Topographic chart illustrating response of milkweed bugs injected parenterally with arsenic. (Based on model illustrated in Figure 5.)

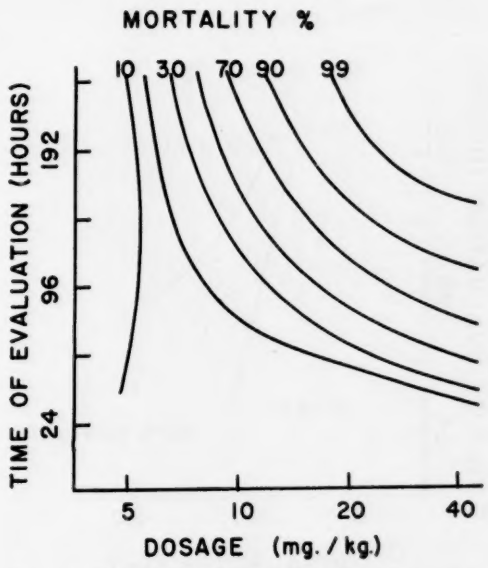

FIG. 8.—Topographic chart illustrating response of milkweed buts injected parenterally with parathion. (Based on model illustrated in Figure 6.)

cant but the disadvantage of indicating only one level of response. Horsfall (1949) has made use of the topographic method with the actual experimental data, without calculation. He has tabulated the dependent variable against the two independent variables and drawn in "by eye" the isometric lines.

The alignment chart illustrated by figure 10 makes possible the interpolation of values for any one variable by aligning the desired points for the other two variables. In these illustrations, the position of the line representing the time variable suggests the difference in the performance of arsenic and parathion. Again, the less importance of the time factor in response to arsenic is emphasized. The alignment chart is perhaps more precise and easier to use than the three dimensional model, but is less graphic for comparative purposes than the topographic chart. Its use is likely to be limited to those variables which can be fitted directly or with suitable transformation to a rectilinear curve.

These methods as presented call for a set of data with sufficient points to permit plotting against both of the independent variables. To get these data may be considered "too much work." If the possibility of misleading conclusions is to be avoided, the only alternative to acquiring the full data is to extrapolate the data in one dimension, the shortcomings of which are well known. Bliss (1937) makes provision for a truncated distribution in his discussion of the survival time-mortality curve, and the use of it permits the termination of observations before the endpoint is reached. Conceivably the time required to kill could be estimated on the basis of two readings after treatment, for two points can determine a straight line. This however, assumes that the mortality is a rectilinear function of time of evaluation (with suitable transformation) and requires the placement of much confidence in the reliability of the two readings. Consequently, such a line would have dubious value, not only because of the extent of extrapolation, but because of the possibility of compound curves being overlooked.

There is some conflicting interest in characterizing compounds in such terms as has been discussed. For the general comparison of insecticides orderly data free from excessive variation are sought. The log-probit dosage-response curve is much more manageable than the sigmoid curve from which it is derived, and curves are smoothed where possible to get the best "average" values for one compound to compare with the best "average" values for another compound. In those cases where variation seems excessive, techniques are improved or increased numbers of replicates are used to cancel out the irregularities. When this can be done, smooth surfaces on three dimensional models, regular curves on topographical charts, and satisfactory alignment charts are all possible, and comparisons between compounds are more simply made. On the other hand, where interest lies in the

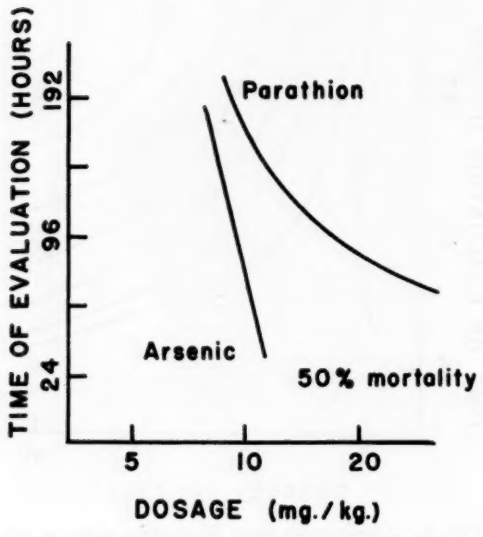

FIG. 9.—Comparison of isometric lines at 50% level taken from Figures 7 and 8.

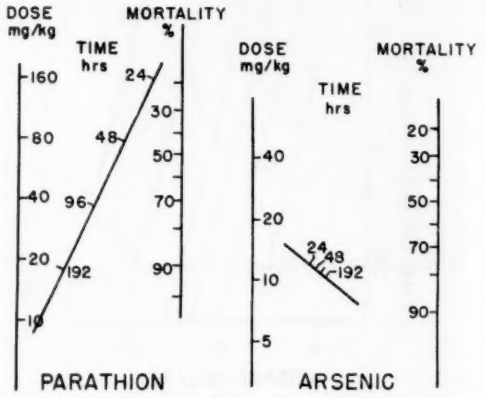

FIG. 10.—Alignment charts illustrating response of milkweed bugs injected parenterally with parathion and arsenic.

performance of compounds in their more fundamental details, the variations may provide very important information, which may be overlooked when sufficient replicates are used to counteract the irregularities of each or when for other reasons compound curves are made to conform to the usual pattern. The relationship between toxicity and dissociation postulated by Dimond *et al.* and also by Yeager & Munson, the interaction between dust dilution and electrostatic charge discussed by Turner, the repellent action of calcium arsenate mentioned by Hansberry and Chiu, and the above mentioned purgative action of parathion all caused trouble in assigning "average" patterns in the respective circumstances, but nevertheless the information suggested by the aberrancies in the patterns is important. In representing such cases, the three-dimensional model based on the actual data as was done by Hansberry and Chiu is better than the models here illustrated based on the calculated, best fitting, straight lines; the "eye fitted" topographic chart used by Horsfall is better than the topographic chart illustrated in figures 7, 8, and 9; and with compound curves the alignment chart cannot be used unless the curves can be divided into components of straight lines.

These graphic methods serve as visual aids in judging the comparative performance of the respective compounds, but there is no mathematical treatment that makes possible a statement without considerable qualification that one compound is so many times more toxic than another. It would be very helpful if this were available, but it is doubtful if so simple a device can be designed.

SUMMARY.—Selected data show that the form of a compound curve and the position and slope of simple curves may change with differences in the time of evaluation after insecticidal treatment. The importance of these changes lies in the fact that in comparative studies misleading conclusions may be drawn relative to the performance of compounds if time of response is not taken into consideration. Methods of graphically representing the three variables of dosage, response time, and mortality are illustrated and discussed, and the desirability is indicated of a mathematical treatment which will permit quantitative discrimination between toxicants and which will take into account the several qualifying factors.

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Pre-Hatching Treatment of Irrigated Lands with DDT, Dichlorodiphenyl Dichloroethane, and Gamma-Benzene Hexachloride for Control of Flood-Water Mosquitoes

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Although a few publications have contained reports on pre-hatching larviciding of flood-water lands, the question of the value and efficiency of such a treatment in the San Joaquin Valley of California has not been fully investigated. In order to evaluate this method of mosquito control, the Consolidated Mosquito Abatement District of Fresno County, California, began experimental operations in pre-hatching treatment in May 1947 and extended them throughout the mosquito propagating season of 1948. In the work undertaken, various insecticides commonly used as larvicides were employed. Particular attention was directed toward the application of DDT, dichlorodiphenyl dichloroethane, and gamma isomer of benzene hexachloride.

The area in which the investigations were conducted is within the confines of the Mosquito Abatement District which encompasses approximately 1000 square miles of the central portion of Fresno County. It is extensively farmed and practically all of the cultivated lands are under irrigation. The soil varies in different localities from sandy loam to silty clay loam and in some locations is underlaid with near-surface hardpan. Seasonal irrigation begins in April and extends through the month of November. Since the condition of the soil prevents rapid penetration of excess water and the frequency of flooding eliminates complete evaporation in many instances, conditions are conducive to the production of *Aëdes* mosquitoes. Additional mosquito propagating waters are expected in this area, and the valley as a whole, with the completion of a vast irrigation project now under construction and with more such projects planned for the future.

The area (Fig. 1) consists mostly of orchards, vineyards, permanent pasture lands and alfalfa acreage. Within the pastures and alfalfa fields the vegetative growth generally varies from 1 to 10 inches in height. These fields are periodically and yet irregularly flooded every 6 to 12 days. The method of irrigation, favorable climatic and environmental conditions, and temperatures frequently attaining 100° F. in this locality commonly promote a 4-day life cycle, from egg to adult, in numerous mosquito broods. In view of the extensive propagating areas and the shortness of the life cycle in many instances, it becomes apparent that it is both economically and physically impractical to supply sufficient man power and spray equipment to produce effective control. Furthermore, the use of spray equipment on wet and muddy fields not only results in considerable damage to fields through "rutting" of the ground and destruction of levees but also tends to contribute to excessive vehicular wear. In the search for a method of mosquito control that would tend to eliminate, if not completely eliminate, the above type of damage and yet remain both practical and economically sound, the pre-hatching treatment method was investigated.

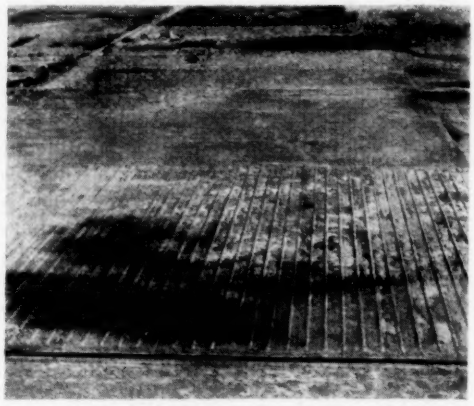

FIG. 1.—Typical cultivated and pasture area, showing irrigational checks, some flooded.

EQUIPMENT.—The equipment employed consisted of a sprayer, with stand-

[1] Manager Fresno Mosquito Abatement.

ard accessories, mounted on a quarter-ton jeep. The sprayer used is an air pressure type, with a 1.5 H.P. gasoline motor and compressor capable of producing 125 lb. pressure. A 60 gallon tank serves as a reservoir. The insecticidal mixture is continuously agitated within the reservoir by means of the standard air agitator of the spraying unit. The materials used were applied by means of a boom-spray modified to meet the demands of local conditions. The boom-spray, mounted on the rear of the vehicle, is a quarter-inch pipe, 42 inches in length, and furnished with four nozzles of two different designs. Two nozzles[1] are placed at right angles to each other at each end of the pipe. The nozzles of local design direct the spray material laterally at right angles to the rig and at a 30-degree elevation. The other nozzles are directed downward and backward and cover the area immediately behind and slightly to the sides of the vehicle. With such an arrangement it is possible to cover a strip of land approximately 30 feet in width when operating at 80 to 85 lb. pressure.

MATERIALS AND MIXTURES.—Selected for detailed study were DDT, dichlorodiphenyl dichloroethane and the gamma benzene hexachloride. The DDT used in this work was a 25 per cent active ingredient, water miscible emulsion, or a commercial product containing 2.2 lb. by weight of toxic ingredient per gallon of emulsion. The dichlorodiphenyl dichloroethane, also in a water miscible emulsion, contained 21.8 per cent of active ingredient, or 1.8 lb. of toxic agent per gallon of emulsion. Only pure gamma benzene hexachloride was used. This was obtained in a wettable-powder mixture containing 4 oz. of pure gamma isomer to 12 oz. of inert materials.

Following standard practices, any emulsible material used was first mixed with equal parts of water before being diluted further. Consequently, 1 gallon of the commercial concentrate was handled in this manner before being added to the 8 gallons of water contained in the equipment reservoir. This gave a total of 10 gallons of prepared mixture of each insecticide for experimental application. The gamma isomer was prepared by mixing 90 grams of the commercial material in 2 gallons of water, and stirring the whole to make a slurry which was added to the 8 gallons of water in the reservoir, making a total of 10 gallons of prepared mixture. In each instance, the mixtures were continuously agitated during spraying operations, particularly so in the case of the gamma-isomer which was found to settle rapidly when left standing.

APPLICATION.—Application of the prehatching treatment method, as practiced here, was conducted between irrigational periods or while the ground was dry. In applying sprays the vehicular speed is of considerable importance. The number of nozzles, the diameter of their orifices, and the operating pressure of the reservoir determine the rate of flow, while the speed of the vehicle determines the amount of toxic material distributed per unit of given area. It was found in this work that a vehicular speed of 8 miles per hour with the spraying apparatus operating at 80 to 85 pounds pressure permitted a discharge of material at the rate of approximately 6 gallons per acre. At the prescribed speed of 8 miles per hour, DDT was distributed at the rate of 1.20 lb. by weight of toxic ingredient per acre, dichlorodiphenyl dichloroethane at 1.18 lb. per acre, and gamma isomer at the rate of .03 lb. per acre. The difference between the amount of gamma isomer as compared with the other materials is accountable to the fact livestock were present in the experimental field. It was felt that higher concentrations of gamma isomer should not be used under such circumstances until more information is made available regarding the toxicity of the insecticide to livestock and vegetation, including forage crops.

The experimental field, as is the case for most pasture lands and alfalfa acreage in this area, was divided for irrigational purposes into "checks" or areas 30 feet wide and 300 feet in length, and each enclosed by small dikes approximately 1 foot in height. These areas were used as units of distribution of the insecticides. One trip with the spraying unit through the length of a check gave complete coverage of that strip.

Certain checks were treated; others, left as controls, were not treated. In all cases, the insecticide was directed onto the ground or on the vegetation as near the ground as possible. Insecticide caught on tall and matted vegetation does not become mixed with the propagating waters,

[1] One of local design; one *Chicago Spray Systems No. 8002*

Table 1.—Results of pre-hatching treatment of irrigated lands with DDT, dichlorodiphenyl dichloroethane and gamma isomer of benzene hexachloride for the control of *Aëdes* mosquitoes. Date of treatment: August 27, 1948. Date of Irrigation: August 30, 1948, Plot area 900 square feet.

Larvicide Applied	Plot No.	Lbs. per Acre Toxic Agent	Larval Count Previous Irrigation No Treatment (Av. per Dip)	Larval Count 4 Days After Treatment (Av. per Dip)
DDT	1	Control	15	15
	2	1.2	10	0
	3	1.2	20	0
	4	1.2	40	0
Dichlorodiphenyl dichloroethane	5	Control	50+	30
	6	1.18	50+	0
	7	1.18	50+	1 per 8 dips
	8	1.18	50+	1 per 40 dips
Gamma isomer of Benzene hexachloride	9	.03	20	8
	10	Control	15	25
	11	.03	7	10
	12	.03	10	25

and is therefore lost as a larvicide. Fortunately, however, it does serve to kill some adults as will be discussed later.

Results.—Prior to the work reported herein, pre-hatching treatment of various fields had been conducted over a long period of time, but these fields, at one time or another had previously undergone the application of larvicides. The field selected for final analysis of the work was chosen because it was typical pasture land and at no time had been subjected to mosquito control work. Periodically the field had been inspected and found to be producing mosquitoes in large numbers. Immediately preceding the application of the pre-hatching treatment the mosquito productivity of the field was recorded check by check area in numbers of larvae per dipper. As shown in table 1, this varied from an average of seven larvae per dipper in some checks to well over an average of 50 in other checks.

Experience disclosed that pre-hatching treatment could be applied any time from 1 to 10 days before irrigational flooding with little or no difference in the effectiveness of the control. In this work all materials used were applied 3 days before the field was irrigated.

As shown in table 1, check No. 1 was left as a control with the results that an equal average number of mosquito larvae were found to be present before and after the pre-hatching treatment of neighboring checks. The next three checks, Nos. 2, 3, and 4, were each treated with DDT at the rate of 1.20 lb. of toxic ingredient per acre. The larval counts in these checks before treatment showed an average of 10 to 40 larvae per dipper. After treatment, no larvea were found in any of the checks. Check No. 5 was left as a control. It also served to separate the checks treated with

Table 2.—Results of treatment with dichlorodiphenyl dichloroethane to control on *Aëdes* mosquitoes in dense vegetation.

Plot No.	Vegetation (Av. Height) Inches	Acres Treated	Pounds Active Insecticide (per Acre)	Date Sprayed	Adults Present 1 Day Before Spraying (Av. Count)	Adults Present 1 Day After Spraying (Av. Count)
				July 1948		
1	12	22	0.54	13	75	5
2	10	5	0.54	21	62	1
3	10	15	0.54	26	45	2
4	18	15	0.54	22	58	3

DDT from those treated with dichlorodiphenyl dichloroethane. Before treatment of the adjacent checks the larval count in check No. 5 averaged 50 plus larvae per dipper; after treatment of neighboring checks, 30 larvae per dipper. This drop in larval count was considered to be natural through the pupation of larvae and emergence of adults. Checks Nos. 6, 7, and 8 were treated with dichlorodiphenyl dichloroethane at the rate of 1.18 lb. of toxic agent per acre. In this instance, all three checks were producing an average of 50 plus larvae per dipper before treatment; after treatment, only a few straggling larvae were found to be present, there being an average range of a larva per eight dippers to one per 40 dippers, The results, therefore, were comparable to those obtained by the application of DDT. Check No. 10 was left as a control, and it was found to contain an average of 25 larvae per dipper after the treatment of adjacent areas with gamma-isomer, or an average increase of 10 larvae between the two periods of inspection. Checks Nos. 9, 11, and 12, were treated with gamma isomer at the rate of .03 lb. by weight of the isomer per acre. As shown in the table, no control of the mosquito larvae was evident, there actually being an increase in number between the period before treatment and that after treatment. It is recognized that the amount of gamma isomer applied was insufficient, but the presence of livestock in the field at all times prevented its application in higher concentrations. However, as observations indicated, if the gamma isomer was applied in proportion equal to that of the other poisons, or even in less amounts, equivalent results would occur. At present the questionable toxicity of gamma isomer to livestock and its cost limit the use of this insecticide for practical purposes.

Subsequent inspections of this and other fields under observation demonstrated that pre-hatching treatment with DDT or its *analog* applied as outlined, produced effective control of the mosquito for a period ranging from 1 to 3 months, or for a maximum of 6 irrigational floodings, depending upon the irrigating cycle. The average effectiveness of the materials was about 6 weeks, or for 3 irrigations. Beyond this time mosquito production in the fields progressively increased.

The application of insecticides between irrigational periods, as practiced in the pre-hatching treatment, resulted in increased efficiency of the entire operation. Vehicular speed and the amount of applied material was brought under more exact control. Since the ground was dry during spraying operations, and in most cases hard, damage to the fields and dikes was reduced to a minimum.

As demonstrated in this work, the pre-hatching treatment method resulted in practical and effective control, and it has now been applied to approximately 4000 acres throughout the district.

DICHLORODIPHENYL DICHLOROETHANE TO KILL ADULTS.—Frequently during pre-hatching treatment of areas for larval control it was obvious that much of the insecticide did not reach the ground in areas containing tall and dense vegetative growth. This material, therefore, was lost as a larvicide since it did not become mixed with the water when the fields were irrigated. On the other hand, however, the insecticide on the vegetation was found to be effective for killing adults. As a result, in some fields where the pre-hatching treatment was not advisable due to the height of the vegetation, this method of controlling the adult mosquitoes became a regular practice.

As shown in table 2, experiments on the control of the adult mosquitoes were conducted in four different areas comprising a total of 56 acres. Each area or experimental plot was treated with dichlorodiphenyl dichloroethane at the rate of 0.54 lb. of the toxic ingredient per acre, or 3 gallons per acre of the prepared mixture. The material was applied in the same manner and with the same equipment as were employed for pre-hatching treatment for larval control. Allowing 1 minute for counting time, the relative numbers of adults were determined by counting the number found on the trouser leg from hip to cuff. Five such counts were made per plot at different locations, and the average number of mosquitoes computed. One day before the areas were treated, the average number of adults ranged from 45 to 75 per counting surface area; 1 day after spraying operations, the average number varied from 1 to 5 per counting surface. Two subsequent applications of the same material on plot No. 1 reduced the number of adults to a point where

satisfactory control was obtained by the end of July, and all insecticidal operations were stopped. In untreated areas mosquito production remained normal.

OBSERVATIONS AND DISCUSSIONS.—During the application of the insecticides, small bodies of water from previous irrigations were encountered in many instances in certain areas or fields, the water having failed to penetrate the soil or evaporate completely. Although these waters, along with the vegetation and dry soil, received the pre-hatching treatment with DDT or dichlorodiphenyl dichloroethane, it was found that larvae were present within the limits of these pools following the recession of subsequent irrigational waters. Furthermore, although present in these semi-permanent waters after treatment, mosquito larvae were not found to be present elsewhere within the treated areas. It appears, then, that the pre-hatching treatment of lands possessing numerous bodies of water of semi-permanent nature will not result in effective or satisfactory control since certain waters will continue to harbor mosquito larvae.

Continued visual observations of livestock and vegetation, including forage crops, revealed neither detrimental effects from the continued use of gamma isomer nor any signs of injuries caused by the use of DDT or its analog as applied in the amounts employed in this work.

Since most of the pre-hatching treatment for the control of flood-water mosquitoes was conducted on pasture lands containing livestock, emphasis was placed on the use of dichlorodiphenyl dichloroethane due to its low toxicity to mammals. Although DDT has been proven safe for application on such fields when dispersed in the amounts applied, in certain areas its use has become unpopular where feed and dairy cattle are concerned, particularly when the insecticide is applied to stock feed material. The application of dichlorodiphenyl dichloroethane has proven satisfactory for control of larvae and adults in all fields treated in this locality.

SUMMARY AND CONCLUSIONS.—The pre-hatching treatment method with DDT, dichlorodiphenyl dichloroethane and the pure gamma isomer of benzene hexachloride for the control of the *Aëdes* mosquito was applied, both experimentally and on a practical basis, on over 4000 acres of irrigated lands in Fresno County, California. DDT and its analog, properly applied at the rate of 1.20 lb. and 1.18 lb. of toxic ingredient per acre, respectively, gave equal and effective larval control for a period ranging from 1 to 3 months, or a maximum of 6 irrigational floodings. The average effective control covered a period of 6 weeks, or the equivalent of 3 floodings, depending upon the irrigation cycle. The gamma isomer of benzene hexachloride, applied at the rate of .03 lb. of the pure isomer per acre, was ineffective as a larvicide in that amount. However, observations indicated that higher concentrations of the gamma isomer would prove as effective as DDT or its analog if applied in comparable, or even smaller amounts.

All insecticides were applied to the ground or to the vegetation as near the ground as possible in order to make the materials available for mixing with the propagating water upon irrigation or flooding. Tall and dense vegetation and pools of standing water decreased the efficiency of the pre-hatching treatment method.

No detrimental effects were observed on vegetation or the feeding livestock due to the treatment of the fields with the three insecticides.

Operation of equipment on dry land resulted in increased operational efficiency and reduced field damage to a minimum.

It is realized that there is a need for further study of the pre-hatching treatment method of mosquito control, particularly in different localities and under different conditions than those presented here. However, from the information gained during this and preceding work conducted in this area, pre-hatching treatment of irrigated lands by means of ground equipment definitely has a future in the control of *Aëdes* mosquitoes. The results obtained, warrant its continued and expanded use.

Deposition of Aerosol Particles

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During the last few years considerable research has been done at Beltsville, Md., on the subject of insecticidal aerosols. One phase of the studies has been the behavior of aerosol clouds in relation to deposition of the particles on insects and on various materials upon which insecticidal deposits are desired. The phases of this study related to the deposition on insects have been presented by La Mer *et al.* (1947) and Latta *et al.* (1947). This paper reports data on the deposition of aerosol particles upon various objects. The subject will be discussed under two headings, deposition in still air and deposition in moving air.

DEPOSITION IN STILL AIR.—There has been considerable disagreement about the deposition of aerosol particles within enclosures. Many workers believe that toxic deposits are made on walls or other vertical surfaces.

Certain physical laws governing the behavior of liquid particles enable us to predict that particles in the size range usually encountered in insecticidal aerosols should settle straight down and therefore deposit only on horizontal surfaces, unless diverted by some force greater than gravity (Gibbs 1924). One of these physical laws tells us that all particles are drawn toward the earth by the force of gravity. This movement toward the earth is resisted by molecules of the gas in which the particles are suspended, in this instance air. When their diameter is greater than the distance between the molecules of the air, there is a uniform resistance due to the bombardment of the air molecules, and the particle falls straight down and quickly attains a uniform velocity. The rate of fall of particles with diameters between 1 and 200 microns under standard conditions can be calculated by Stokes' law.[2]

Known factors that can overcome gravity and divert the particles from their straight fall include temperature gradients wherein very small particles will move toward a cold surface; light rays, in which small particles are repelled; air currents, including sound waves; electrical fields, wherein particles are drawn towards the opposite pole; and Brownian movement (DallaValle 1943). Brownian movement will occur however, only when the diameter of the particles is less than the distance between the molecules of the air, or less than 0.1 micron in air of 70° F. Then the particle changes direction while falling, owing to the bombardment of the air molecules from various directions.

Tests were made with DDT aerosols to determine the proportional amount of deposition on horizontal and vertical surfaces. Aerosols were released in enclosures under conditions usually existing in normal use of aerosols in buildings. The amounts deposited were compared (1) by confining insects on surfaces exposed in positions horizontal and perpendicular to the discharge of the aerosols, (2) by chemical analysis of DDT, (3) by visual observation of deposits made possible because of a dye included in the aerosol solution (also by spectrophotometric determinations of the dye), and (4) by measuring and counting particles deposited on exposed slides.

Insects confined on 9-inch-square panels exposed to aerosols while in a vertical (attached to wall) position did not die, but among insects on the floor panels exposed to the same aerosol the mortality was as high as 94 per cent.[3]

In the studies with insects La Mer and co-workers demonstrated that insects exposed to homogeneous aerosols of various particle sizes were killed in direct proportion to the settling rate of the particles. When insects were removed at given time intervals, the mortality was in proportion to the amount of insecticide that had settled out on the insects. When adequate time was allowed for all particles to settle out, the mortality was the same for all particle sizes not above a critical value, which for *Aëdes aegypti* mosquitoes was

[1] These investigations were conducted under funds allotted to the Bureau of Entomology and Plant Quarantine by the National Military Establishment.

[2] The rate of fall of aerosol particles as calculated by Stokes' law with the use of standard conversion factors would be $V = 0.00592\rho D^2$, where V is the velocity in feet per minute, D is the diameter of the aerosol particle in microns, and ρ is the density in grams per cubic centimeter. An aerosol particle 10 microns in diameter with a density of 0.9 will fall 1 foot in 1.9 minutes.

[3] These tests were performed by O. C. McBride and W. N. Sullivan.

about 10 microns in diameter.

Samples of DDT aerosols collected on aluminum panels exposed on the walls and floor of an enclosure were analyzed chemically by the Schecter & Haller method.[3] The amount of DDT recovered on the wall panels was less than 1 per cent as great as that on the floor panels.

An aerosol having particles with a mass median diameter of 15 microns and containing a dye was released in an enclosure, and samples were collected on objects of various shapes and on vertical and horizontal slides.

A paper cylinder approximately 3.5 inches in diameter by 7 inches long (1-quart container) laid on its side had the heaviest deposit at the crest of the cylinder, from which point it tapered off towards the sides. There was no deposit on the receding walls below the widest part of the cylinder. A cube with two opposite surfaces open had a good deposit on the top surface, but no discernible amount on the side walls either inside or out. There was a light deposit all over the inside bottom. A paper cylinder laid on its side with a 0.5 -inch hole in each end had a light deposit inside on the lower half of the cylinder. A similar cylinder with a hole in only one end had no visible deposit inside. Another cylinder on its side with one end completely open showed some deposit on the lower half of the inner walls, but much less than did the cylinder with holes in each end. An upright cylinder with a 0.125-inch hole in the top end had a deposit on the bottom directly beneath the hole, the color being intense at the center and fading towards the walls.

The deposit on the slides was washed off and analyzed on a spectrophotometer. There were no deposits on the vertical slides, and the horizontal slides had close to the expected amount. Vertical slides were also examined under a microscope, but no dye deposit was found. Any protrusions from wall surfaces, such as nails, cleats, fibers, or splinters, showed dye on the top of the horizontal surface. Slides exposed vertically and horizontally were examined under the microscope for the purpose of measuring and counting the particles deposited. No particles were found on vertical slides in a number of trials, but the horizontal slides contained approximately the expected amount of residue.

These tests indicate that, in general, where aerosols are applied within enclosures, there is very little or no deposition on walls or other vertical surfaces, and the particles of the aerosol settle almost entirely upon the top of horizontal surfaces. The settling deviates from the perpendicular, probably because of slight convection currents, as evidenced in the deposit within the open-faced cube and the horizontal cylinder as described above. Even where deviation occurred, however, the deposition was still on horizontal surfaces.

DEPOSITION IN MOVING AIR.—Considerable experimentation was carried on to determine whether deposition of aerosol particles in moving air would be in accordance with the behavior of liquid particles of other types. A publication by a German engineer, Willy Sell (1931), concerning the removal of particles from air by fifters discloses a great deal of information on the subject. He found that particles in a moving current of air, in addition to settling out, deposit selectively on the surfaces perpendicular to the air flow. When air is deflected around an object, the particles suspended in the air stream tend to resist deflection and continue toward the object. The probability of the particles striking the object varies directly with the square of their diameter and their velocity, and inversely with the size of the object, and varies to some extent with the shape of the object. The percentage of the aerosol deposited can be computed from graphs (reproduced in Fig. 1) in Sell's report, if the momentum of the particle and the size and shape of the object are known. A ball shape collects the least deposit, a circular disc next, then a cylinder, a rectangular plate, and a concave surface the most. This selectivity applies also on moving objects.

Sell developed a formula to express the efficiency of deposition of oil particles on objects of various shapes. This efficiency is shown to vary according to a value δ which can be computed by using standard conversion factors as follows:

$$\delta = \frac{0.00005\ D^2V}{S}$$

where S = size (greatest width) of the object in inches, D = diameter of the particle in microns, and V = velocity in miles per

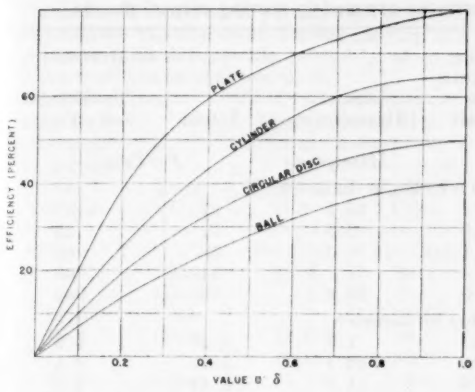

FIG. 1.—Efficiency of deposition of particles on different shaped objects according to Sell.

hour. The efficiency is greatest when $\delta = 1$.

According to this formula, if a mosquito 0.025 inch in width is flying through an aerosol cloud at 2 m.p.h., particles 15.81 microns in diameter would deposit with greatest efficiency.

$$D^2 = \frac{0.025 \times 1}{0.00005 \times 2} = 250$$

$$D = 15.81 \text{ microns}$$

Latta and coworkers found in their insect studies that the deposition of moving aerosol particles on mosquitoes, as evidenced by the mortality, varies with the product of the diameter squared and the velocity up to the point of maximum efficiency. The optimum particle diameter was indicated to be in the neighborhood of 12 microns for a mosquito in a 2-m.p.h. wind, from data in table 2 of Latta's report. The other values in Sell's curves representing efficiency of deposit according to δ in the formula mentioned above, correspond to the decreases in deposition found by Latta and co-workers, as evidenced by the increased amount of insecticide needed to produce equivalent mortality.

Tests were made with house flies in the same manner as the tests with mosquitoes. When the D^2V values were plotted, the slope of the curve became horizontal near a value of 2000, which indicated the point where efficiency of deposition no longer increased. At 4 m.p.h. a particle diameter of 22.4 would be derived from this value. The optimum particle size for a house fly in motion at 4 m.p.h. (the calculated speed of flight), on the assumption that the fly is 0.1 inch in diameter, would be 22.4 microns according to Sell's formula.

The deposition on various surfaces was measured by exposing materials representative of several different surfaces in a wind tunnel to aerosol clouds moving at velocities of 2 to 16 m.p.h. The wind tunnel was essentially the same as the one used in insect tests reported by Latta and co-workers, except that it was lengthened to 61 feet. The aerosol was introduced at the mouth of the tunnel, and the materials were exposed to the moving aerosol cloud at a point 47 feet from the mouth. The aerosol could be admitted or excluded from the wind tunnel at will.

The aerosols were prepared in a La Mer-Sinclair homogeneous aerosol generator similar to the one used in the insect studies. The aerosol solution contained approximately 5 per cent of *p, p'*-DDT dissolved in a heavy petroleum fraction having practically the same vapor pressure as DDT.

The amount of aerosol introduced into the wind tunnel was computed by multiplying the output per minute by the number of minutes the aerosol was released into the tunnel. The rate of generation was obtained by weighing the amount of aerosol absorbed in a glass-wool filter in 10 minutes. The exact percentage of DDT in the aerosol was computed by analyzing the output absorbed in the glass-wool filter by means of a spectrophotometer using the Schecter & Haller method.

The particle size was determined by trapping a sample of the aerosol cloud in a bell jar as it issued afrom the generator, and allowing it to settle on a slide. The particles were measured under a high-power microscope, with due allowance for the spread on the slide. From these measurements the mass median diameter was determined. The mass median diameter of the aerosol cloud at the point of deposition on the materials under test was determined by many samplings to be the same as at the generator.

The materials chosen to represent the selected types of surfaces were cut into discs of various sizes and exposed to the aerosol. The discs were held crosswise to the air stream in the wind tunnel by a rack made of very fine wire. The amount of deposition was determined by

Table 1.—Deposition of aerosol on various surfaces exposed to moving aerosol clouds.

Mass Median Diameter of Particles	Velocity	D^2V	Aerosol Available for Deposit	Aerosol Deposited	Efficiency of Deposition	
					Actual	Predicted by Sell's Formula
Microns	*M.p.h.*			*Micrograms*	*Per Cent*	
			16-mesh wire-cloth discs 6 inches in diameter			
8.4	2	141	62.5	35.5	57	55
9.0	2	162	6.8	3.5	52	59
11.9	2	284	32.1	18.5	58	65
8.4	8	564	62.5	52.2	84	65
10.1	8	817	44.0	32.0	73	65
			Glass discs $2\frac{3}{4}$ inches in diameter			
16.6	8	2200	1355	7.7	0.57	4.0
13.0	8	1350	2415	16.1	0.67	2.4
13.3	8	1415	2670	11.7	0.44	2.6
10.7	8	915	1985	8.9	0.45	1.9
19.1	8	2920	3091	13.3	0.43	5.8
			2578	20.0	0.78	5.8
18.0	2	648	2500	2.1	0.08	1.2
				3.4	0.14	1.2
			Filter-paper discs $2\frac{3}{4}$ inches in diameter			
17.6	8	2480	695	9.3	1.34	4.5
18.5	8	2730	1083	13.0	1.20	5.1
				15.4	1.42	5.1
				10.0	1.08	5.1
20.2	2	815	1790	5.0	0.28	1.5
				8.0	0.45	1.5
			Leaf discs $2\frac{3}{4}$ inches in diameter (smooth side toward aerosol)			
33.7	4	4540	1005	9.2	0.92	8.2
			Leaf discs $2\frac{3}{4}$ inches in diameter (rough side toward aerosol)			
22.5	4	2020	1922	37.6	1.95	3.7
14.8	4	876	872	10.2	1.17	1.6
				12.0	1.38	1.6
18.0	4	1295	1640	10.0	0.61	2.3
				8.0	0.54	2.3
14.5	4	841	1478	12.0	0.81	1.5
				16.3	1.10	1.5
				14.6	0.99	1.5
25.8	8	5330	3955	93.6	2.36	9.6
13.5	8	1460	1149	26.0	2.26	2.7
13.5	8	1460	1896	25.8	1.32	2.7
18.0	8	2590	952	22.3	2.32	4.7
				12.3	1.29	4.7
				9.2	0.97	4.7
				17.0	1.79	4.7
16.7	8	2230	1091	42.5	3.87	4.1
				21.7	1.99	4.1
17.6	8	2480	1390	22.0	1.60	4.5
			695	14.7	2.12	4.5
				8.0	1.15	4.5
25.8	2	1330	3955	27.0	0.68	2.4
13.5	2	365	2275	9.5	0.42	0.7
11.8	2	278	1742	7.8	0.45	0.5
				8.3	0.48	0.5
				5.9	0.34	0.5
			Leaf discs 1.625 inches in diameter (rough side toward aerosol)			
20.2	2	817	855	10.0	1.17	2.4
	8	3265	855	35.0	4.09	9.5
18.0	4	1295	533	6.8	1.23	3.8
			Leaf discs 6 inches in diameter (rough side toward aerosol)			
9.0	2	162	13,160	20.0	0.15	0.13
	8	648	13,160	32.5	0.25	0.54
			11,175	31.0	0.28	0.54
			Filter-paper discs 6 inches in diameter			
13.0	8	1350	8030	30.9	0.38	1.1
				53.9	0.67	1.1

Table 2.—Deposition of particles on front and back of discs exposed to an aerosol moving at 8 m.p.h., as indicated by the mortality of mosquitoes confined on their surfaces.

Mass Median Diameter of Particles	Type of Disc	Mortality of Mosquitoes Confined on—	
		Front of Disc	Back of Disc
Microns		*Per Cent*	*Per Cent*
7.9	Glass	13.4	59.7
8.0	Glass	7.8	70.5
14.6	Glass	4.7	79.0
15.8	Glass	12.0	48.0
	Leaf	79.0	33.0
18.5	Glass	1.7	1.6
19.3	Glass	65.0	11.0
	Leaf	99.0	22.0

weighing or by chemical analysis. The efficiency of deposition was computed by comparing the amount of DDT recovered with the proportional amount that would pass the area occupied by the disc. This proportional amount was determined by multiplying the total amount of DDT admitted to the tunnel in the aerosol cloud by the percentage of the total cross-sectional area occupied by the disc.

Four materials were exposed in the wind tunnel: (1) 16-mesh wire cloth cut into 6-inch discs with a total cross-sectional area of 9.82 square inches (wire diameter 0.012 inch), (2) glass discs 2.75 inches in diameter, (3) discs of filter paper 2.75 and 6 inches in diameter, and (4) leaves of the rubber tree *Castilla elastica* cut into discs of 1.625, 2.75 and 6 inches in diameter. The leaves had one surface smooth and one rough.

The deposits on these materials are presented in table 1. The amount of aerosol calculated to pass through the area occupied by the disc is called the aerosol available for deposit. According to the evidence presented in the insect studies (Latta *et al.* 1947) the rate of deposition should be proportional to D^2V until the maximum rate of deposit is reached. Therefore the D^2V values are presented in table 1 for ready reference. The efficiency of deposition, as calculated from Sell's formula for each material on the basis of its size is also given for comparison.

Table 3.—Deposition of particles on front and back of discs exposed to an aerosol moving at 8 m.p.h., as indicated by analysis.

Mass Median Diameter of Particles	Type of Disc	Amount of Aerosol Deposited on—	
		Front of Disc	Back of Disc
Microns		*Micrograms*	*Micrograms*
11.3	Glass	48	112
		70	170
		7.7	18.9
15.3	Leaf	47.5	15
		5.3	1.7

Table 4.—Sizes of particles deposited on the front and back of discs exposed to an aerosol moving 16 m.p.h.

Mass Median Diameter on—		Maximum Diameter Found on—	
Front of Disc	Back of Disc	Front of Disc	Back of Disc
23.5μ	8.6μ	39.5μ	19.3μ
28.5	9.7	52.4	17.3
23	13.5	45.8	21
	21.3	39.8	31.3
22.2	16.4	32.7	28

An effort was made to simulate wet surfaces by wetting leaf sections with glycerol. Leaf sections were also allowed to wave in the air stream, being suspended from one point of the margin only. No perceptible differences resulted; so these tests were not segregated from the others.

The agreement between the efficiency of deposition measured in moving aerosols and the efficiency predicted by Sell's formula was very good. Sell's predicted efficiency was higher than the actual efficiency when the deposit was low.

It was found that the discs also had a deposit on the back side, a factor not considered by Sell. The relative amounts deposited on front and back were determined from (1) the mortality of female mosquitoes confined on the surface for 24 hours, (2) the amount of DDT by analysis, and (3) the mass median diameter of the particles on each side. The results of these determinations are given in tables 2, 3, and 4.

These data indicate that the larger particles deposit on the front of the discs and the smaller ones on the back. The division point between the two is apparently a function of the velocity of movement, and perhaps of the character or thickness of the disc. At 8 mph. the division point is apparently near a particle 15 microns in diameter. It can be noted in table 2 that for mass median diameters below 15.8 the larger part of the deposit is on the back

of the disc, as evidenced by the greater mortality of mosquitoes, where as for greater diameters the deposit is heaviest on the front. This indication is supported by the data in table 3.

At 16 mph. a slightly higher division point is indicated, as shown in table 4. The mass median diameters on the fronts of discs range from 22.2 to 28.5 microns, where those on the back range from 8.6 to 21.3.

SUMMARY.—The deposit of aerosol particles on various surfaces was measured in still air and moving air, to follow up studies in which the deposition on mosquitoes had been determined from the resulting mortality. In still air the particles tended to settle straight down, unless deviated by some force greater than gravity. In general there are usually some air currents that interfere with the particles settling straight down. Even when deviation occurred, practically all deposition was on horizontal surfaces, or upon horizontal protrusions from vertical surfaces. These results were determined from mortality of insects confined on surfaces that were previously exposed to aerosols in vertical and horizontal positions, by chemical analyses of DDT on vertical and horizontal slides, by visual observation of deposits of a dye incorporated in the aerosol solution, and by measuring and counting particles deposited on vertical and horizontal slides.

The optimum particle size to use on insects was found to increase with the size of the insect. The optimum diameter for mosquitoes was 15.81 microns as compared with 22.4 microns for house flies.

The deposition on discs of wire cloth, glass, filter paper, and leaves exposed to aerosol clouds moving at 2 to 16 mph. was measured. These deposits agreed well with the deposit predicted by a formula developed by Sell.

It was found that the smaller particles tended to deposit on the backs of the discs and the larger ones on the front. This division occurred at a particle diameter of about 15 microns at 8 m.p.h., as determined by the relative amount of deposit on each side. At 16 m.p.h. the division point was slightly higher.

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Residual Action of Low Vapour Pressure Fumigants[1]

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The application of fumigants to local portions of a bulk material or to individual machines in a large space is a common practice, but little attention has been paid to the special requirements for this type of fumigation. The sterilization of soil, the fumigation of local zones in large bulks of grain, and the fumigation of individual machines in flour mills are examples of local or "spot" fumigation. The common disadvantage in such applications is that the fumigant vapours cannot be confined, as they are in chamber fumigation or the fumigation of a sealed building, so that there is a sharp gradient in vapour concentration between the point of application and the surrounding space. It follows that excessive quantities of fumigant must be applied to achieve high mortality of insects in the fumigated zone and that re-invasion from the surrounding zone may occur as soon as the fumigant is dissipated.

Flour mills place considerable reliance on fumigants applied in individual mill machines to retard the development of insect infestation between general fumigations of the entire plant. In these machines insects find ideal conditions for development in accumulations of "dead"

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cereal stock, and from the machines they may be spread throughout the milling system. The machines are of loose construction and necessarily open to the rest of the system so that no more than a transitory insecticidal effect is to be expected from the application of highly volatile fumigants. Provided an adequate amount is applied, the initial mortality may be high, but the fumigant is soon dissipated and re-invasion commonly occurs, often obliterating the temporary gain.

Obviously then, this type of fumigation has special requirements. To be successful, the fumigant vapours must be retained for considerable periods at toxic concentrations in cereal materials held under semi-open conditions. Thus, many of the requirements for ordinary fumigation are reversed. Low vapour pressure and slow penetration appear to be advantages, maintaining a reservoir of the fumigant and retarding its loss from the cereal. If low vapour pressure is indeed an advantage then a corollary requirement is a high absolute toxicity so that the relatively low vapour concentration will achieve the desired insecticidal effect. The requirement that the fumigant should be readily removed from the stock by aeration is of minor concern since the "dead" stock under fumigation is presumed to remain in the machines without mixing with the moving mill stream.[2]

The following study appears to support the hypothesis that fumigants of low vapour pressure and high toxicity best meet the requirements for local fumigation.

MATERIALS AND METHODS.—Seven fumigants known to be highly toxic to insects and exhibiting a wide range of vapour pressures were selected (Table 1). Four of the compounds are well-known fumigants with vapour pressures ranging from high to moderately low; gamma benzene hexachloride was chosen as a fumigant compound with an exceedingly low vapour pressure. But the interest in this study centers on two new fumigants with vapour pressures intermediate between gamma benzene hexachloride and the group of conventional fumigants. Hexachloropropene and *symm.*-heptachloropropane have been shown (Brown *et al.*, 1948) to have a high general toxicity for certain insects and this toxicity is attributed to the powerful fumigant action of these compounds. All fumigants tested are liquids at room temperature except gamma benzene hexachloride, which was applied as a 40 per cent solution in acetone.

Adults of *Tribolium confusum* Duv. were exposed to the fumigants in open beakers containing whole wheat flour. Two milliliters of the fumigant were deposited on blotting paper in the bottom of the beaker, which was then filled to a depth of 3 inches with 375 grams of flour. A wire gauze prevented the flour from coming in contact with the liquid fumigant on the blotter, and the insects were enclosed in a cylindrical wire gauze cage 1 inch in diameter and 3 inches long. Thus, the bottom of the insect cage rested close to the deposit of fumigant and the top was close to the surface of the flour. The cage was stoppered at both ends with cork and partitioned with a cork diaphragm into an upper and lower section to enable evaluation of the insecticidal effect below, and near the surface of the flour.

Twenty-five insects were placed in each section of the cage, which was also filled with flour. All tests except that with heptachloropropane were carried out in duplicate. Except where otherwise stated, the insects were exposed in the flour over the fumigant for 4 days; the resultant mortality was assessed 3 days after removing the insects to fresh flour. Because the normal mortality of *Tribolium* adults would be expected to be low over this short observation period (7 days), controls were not maintained on each of the approximately 380 mortality determinations reported here; however, lots of 25 insects drawn from the same population from time to time during the course of these experiments and held under the same conditions as the test insects usually showed no mortality or, at the most, 2 insects dead over the 7-day period.

RESULTS.—Table 1 shows that in open vessels of flour, increasing duration of toxic effect is associated with decreasing vapour pressure of the represented fumigants until, at the very low vapour pressure exhibited by gamma benzene hexachloride no mortality occurs. Excluding gamma benzene hexachloride, table 1 shows that the duration of toxic effect was extended progressively with fumigants of

[2] This has been demonstrated to be the case in elevator boots.

Table 1.—Duration of toxic effect of fumigants in open vessels of flour.

Fumigant	Vapour Pressure (mm. Hg., 25° C)	50–100% Mortality (days)	100% Mortality (days)
Acrylonitrile	117.0	2	1
Chloropicrin	24.0	2	2
Ethylene dibromide	13.5	20	12
Dichloroethyl ether	3.0	28	0
Hexachloropropene	0.3[2]	172	66
Symm.-heptachloropropane	0.1[2]	176	112[3]
Gamma benzene hexachloride	2.1×10^{-5}	0[3]	0

[1] Terminated while still 100% effective.
[2] Determined by W. W. Hopewell, Experimental Station, Suffield, Alberta.
[3] Terminated at 50 days.

progressively lower vapour pressure. The one exception was dichloroethyl ether, which failed to give 100 per cent mortality at any time. The mortalities shown represent the gross mortality of insects exposed in both the upper and lower sections of the cages; and in the case of dichloroethyl ether, insects exposed near the surface of the flour never suffered complete mortality.

Figure 1 relates the mortality of insects exposed in open vessels of flour to the length of time the flour had been held over a deposit of certain of these fumigants. Flour exposed over ethylene dibromide, a fumigant of moderately high vapour pressure, gave a high mortality of *Tribolium* immediately; but the toxic effect was of relatively short duration. Conversely, hexachloropropene, with a vapour pressure of 0.3, gave low mortalities immediately; but with increasing exposure of the flour to the fumigant the mortality

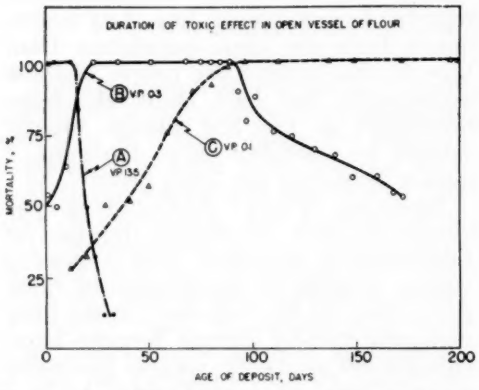

FIG. 1.—Mortality of *Tribolium* adults exposed for 4-day periods in flour over a 2 ml. deposit of: Ⓐ, ethylene dibromide; Ⓑ, hexachloropropene; Ⓒ, *symm.*-heptachloropropane.

Table 2.—Per cent mortality of *Tribolium* exposed in open vessels of flour over hexachloropropene.

Initial Exposure of Flour to Fumigant (days)	Subsequent Insect Exposure Periods (days)			
	1	2	3	4
0	0	0	0	56
5	30	50	56	50
10	50	86	58	74
23	54	92	100	100
35	88	100	100	100

increased to 100 per cent at 23 days and was maintained at that level for 66 days. *Symm.*-heptachloropropane, with a still lower vapour pressure, showed low mortalities for a still longer period, but complete mortality was achieved at 88 days and maintained for 112 days, when the experiment was terminated.

These experiments indicated that hexachloropropene was a particularly interesting fumigant, and further studies were made with it.

Exposure of insects to the fumigant for a 4-day period gave no information on the rate of mortality induced by hexachloropropene or on the possibility that the mortality rate might be influenced by the length of time the flour had been held over the fumigant. Accordingly, insects were exposed for periods of 1 to 4 days in flour that had been exposed over a 2 ml. deposit of hexachloropropene for various lengths of time. In this experiment, 4 of the insect cages were placed in flour over hexachloropropene and one was removed each day thereafter; the last cage removed had therefore been exposed for 4 days. It should be noted that the flour-to-fumigant exposure period increased simultaneously with the length of time the insects were exposed in the flour. Insects exposed in fresh flour over a deposit of hexachloropropene showed no mortality for exposures up to 3 days, but an appreciable mortality resulted from 4 days' exposure. This mortality occurred almost entirely in the lower half of the vessel. Table 2 shows that the mortality increased with increasing exposure of the flour to the fumigant until, after 35 days, insects exposed in the flour for only 1 day suffered 88 per cent mortality.

Insects exposed near the free surface of the flour, that is, in the upper section of

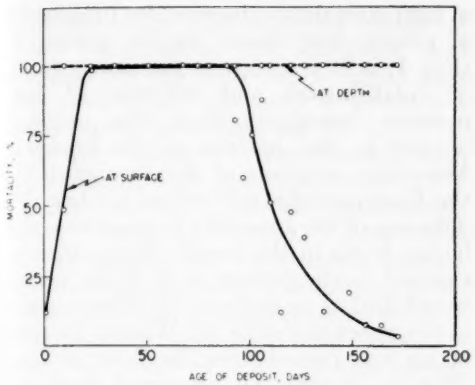

FIG. 2.—Mortality of *Tribolium* adults exposed for 4-day periods at depth and near the surface of flour over hexachloropropene in open vessels.

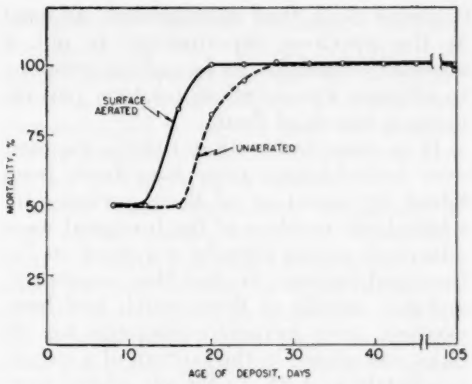

FIG. 3.—Mortality of *Tribolium* adults exposed for 4-day periods to a deposit of hexachloropropene in open vessels of flour with and without aeration of the flour surface.

the cage, generally showed lower mortalities than insects exposed deep in the flour. This effect is illustrated for hexachloropropene in figure 2. *Tribolium* adults exposed in the lower half of the flour showed 100 per cent mortality throughout the entire period. But near the surface of the flour, 100 per cent mortality was not achieved until about 30 days, and after a further period of 66 days, the toxic effect showed a slow decline. During the period of optimum mortality, the toxic effect of hexachloropropene appeared to be operative at about 0.375 inch below the surface of the flour. Insects in the upper section of the flour-filled cage were free to move to within 0.375 of an inch of the free surface of flour in the vessel before being blocked by the cork stopper, and dead insects were invariably found clustered immediately under the stopper.

The effectiveness of hexachloropropene for long periods close to the flour-air interface, where the vapour concentration would be expected to fall off sharply, was considered interesting and prompted a study of the effect of passing air over the flour surface. This would simulate a practical condition in flour mills, where a current of air passes through many types of machines and thus over the dead stock under fumigation. A household electric fan with 6-inch blades was operated at normal speed and directed a strong current of air over the surface of the flour in a beaker at a distance of one foot. Figure 3 shows the effect of aerating the flour surface on the mortality of insects. When the surface of the flour was aerated, 100 per cent mortality was achieved 8 days before the same mortality level was reached without aeration. After the mortalities became equal, no appreciable difference in mortality of insects under the aerated or unaerated condition was observed up to the time the experiment was terminated at 105 days.

A number of tests were made with unconfined insects which were released on the free surface of flour over a 2 ml. deposit of hexachloropropene. The insects were free to remain on the surface of the flour or to burrow to a depth of one inch, where a wire gauze partition prevented them from moving deeper and facilitated removal of the insects for counting. Twenty-five *Tribolium* adults were used for each mortality determination. The following are representative results:

Flour to fumigant, days of exposure...	29	41	73	85	97	101
Insect exposure, days.	9	7	4	4	4	4
Mortality, per cent...	100	88	32	72	20	76

No marked tendency for the insects to remain on the flour surface was observed, and dead insects were usually recovered from beneath the surface of the flour. It seems likely that insects that burrowed beneath the surface and remained there for some time were killed, while those that chose to remain at or near the surface survived. The erratic differences in observed mortality might be accounted for if individual caprice or the sex and maturity of individual insects affected the choice between protracted burrowing or remaining near the flour surface. At any rate,

it seems clear that confinement, as used in the previous experiments, is not a necessary condition for hexachloropropene to exercise a toxic effect for long periods in open vessels of flour.

It is conceivable that insects exposed over hexachloropropene may have been killed by ingestion of flour particles on which toxic residues of the fumigant were adsorbed, rather than by exposure to the fumigant vapour. To test this possibility, a 5-gm. sample of flour which had been exposed over hexachloropropene for 20 days was placed in the bottom of a weighing bottle and 25 *Tribolium* adults were placed in the flour; another 25 insects were exposed on a wire gauze screen above the fumigated flour and the bottle was closed. The experiment was carried out in triplicate for exposure periods of 4, 8, 18, and 24 hours. No significant difference was observed in mortality of insects exposed *in* the flour and of those exposed in the air *above* the flour. It seems reasonable to conclude that insects exposed in flour over hexachloropropene were killed by the free vapour of the compound present in the interstitial air spaces.

DISCUSSION.—The marked increase in duration of toxic effect observed for low vapour pressure fumigants, as compared with fumigants of moderate to high vapour pressure, does not follow directly from the slower rate of volatilization and the maintenance of a reservoir of unvolatilized fumigant for considerable periods of time. Other factors are involved. One of these is a high absolute toxicity, for otherwise the vapour concentration produced by low vapour pressure compounds under semi-open conditions would be insufficient to kill insects. The remarkable duration of toxic effect found for hexachloropropene for instance, coincides with Brown's finding (unpublished work, Experimental Station, Suffield, Alta.) that 100 per cent mortality of *Tribolium* adults resulted from exposure to concentrations as low as 1 cu. mm./l. of air. Other factors tending to extend the duration of toxic effect are slow diffusion associated with high molecular weight (hexachloropropene 247), and the tendency for low vapour pressure fumigants to be strongly sorbed on cereal products (Fisk & Shepard, 1938).

The present observations may be reasonably related to these factors. The progressive retardation of the initiation of high mortalities observed for fumigants of progressively lower vapour pressures (Fig. 1) is in accord with the slower rates of volatilization and diffusion of low pressure fumigants from the original deposit in the bottom of the beakers. Moreover, sorption of the fumigant by the flour particles will retard further the diffusion of the fumigant to progressively higher levels in the beaker. Thus, insects exposed in the bottom half of the vessel were killed at an earlier stage than insects in the upper half (Fig. 2). When a current of air was passed over the flour surface (Fig. 3) it may be presumed that air currents were set up in the body of flour which accelerated the normally slow diffusion of hexachloropropene and resulted in complete mortality of the insects sooner than without aeration.

As the sorptive capacity of the flour for the gas is slowly satisfied, increasing amounts of free vapour become available to kill insects until, in the case of hexachloropropene (Table 2), after 35 days the vapour concentration in the interstitial air spaces must be close to the figure of 1 cu. mm./l. indicated as necessary for complete mortality of *Tribolium* adults.

At this stage, a state of dynamic equilibrium may be envisaged in which desorption of gas from the free surface of the flour is compensated by diffusion from the lower layers as long as a reservoir of unvolatilized fumigant remains. If this is indeed the case, then failure of the surface layer to give complete mortality and the subsequent slow decline of mortality (Fig. 2) occur after the liquid fumigant has been entirely volatilized, and desorption from the flour surface then results in actual reduction of vapour concentration and a corresponding reduction of insect mortality.

With fumigants of high vapour pressure, the processes of volatilization, diffusion, sorption, and subsequent desorption take place rapidly so that considerable quantities must be applied if the insects are to be exposed to a toxic concentration for even short periods. With fumigants of low vapour pressure, the same processes are retarded so that, granted a high toxicity, the application of relatively small quantities will keep the flour under continuous fumigation for considerable periods. The results obtained with gamma benzene hexachloride (Table 1) suggest a

limit at which the retarding effects of slow volatilization and diffusion, and sorption on the flour are so great that long periods are necessary to produce a toxic vapour concentration.

In the search for new fumigants, a moderate to high volatility is generally regarded as an essential requirement. Thus, Shepard (1939) comments, "Unfortunately the substituent radicals that increase the toxicity of simple hydrocarbon structures also decrease volatility." This position might well be reconsidered from the point of view of the special requirements for local fumigation. The use of low vapour pressure fumigants will certainly be limited by the difficulty of aerating the adsorbed fumigant from the product. Studies are in progress to determine the value and feasibility of using low vapour pressure fumigants under mill conditions where the mill stream contacts only momentarily the "dead" stock under fumigation. Whether or not this should prove successful, the principle that low vapour pressure fumigants offer an advantage for the special conditions of local fumigation, and the laboratory demonstration of the efficacy of certain low vapour pressure fumigants under such conditions, seem worth recording.

SUMMARY.—Local application of highly volatile fumigants in milling machinery achieves only a transitory insecticidal effect because the fumigant is rapidly lost from the semi-open space and reinvasion by insects commonly occurs. Fumigants of low vapour pressure and high toxicity would be expected to remain effective for longer periods. This has been demonstrated to be the case for a series of fumigants of different vapour pressures applied to flour in open vessels.

Under these conditions, fumigants of high vapour pressure gave an immediate high mortality but failed to maintain this effect for more than a few days; fumigants of low vapour pressure gave low mortalities immediately, but high mortalities were gradually achieved and were maintained for periods as long as 112 days; a fumigant of very low vapour pressure gave no mortality.

A new fumigant, hexachloropropene (v.p. 0.3), was subjected to further tests. Exposed insects were killed sooner and higher mortality was achieved with increasing length of exposure of the flour to the fumigant. Aeration of the flour surface shortened the time required for hexachloropropene to give complete mortality of exposed insects. Slow rates of volatilization and diffusion, strong sorption on the flour, and a high absolute toxicity are indicated as factors involved in the marked duration of insecticidal effect obtained with low vapour pressure fumigants.[1]

[1] ACKNOWLEDGMENTS.—Supplies of hexachloropropene and *symm.*-heptachloropropane, as well as information on the physical and insecticidal properties of these compounds, were made available through the courtesy of The Defence Research Board, Experimental Station, Suffield, Alta.

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Recovery of Parathion, DDT and Certain Analogs of Dichlorodiphenyl-Dichloroethane from Treated Crops[1]

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The purpose of this investigation is twofold: First, to determine the amount of toxic residues remaining on dusted and sprayed crops at harvest time under New Jersey conditions, and second, to ascertain whether the new toxicants are absorbed or translocated into edible plant tissue.

Due to the outstanding performances of parathion-DDT and its two close analogs dichloro-diphenyl-dichloroethane and methoxychlor in controlling many species of agricultural insect pests, their use as insecticides is rapidly expanding. In addition to being highly potent against insects, they are also claimed to possess varying degrees of toxicity to higher animals when ingested in appreciable quantities, Neal & Von Oettingen (1946), Lehman (1948). It is also known that DDT and dichlorodyphenyl dichloroethane are stored in body fat and secreted in milk. For further information on the toxicology of the four new insecticides here discussed, the reader is referred to the following publications: Woodard *et al.* (1944), Neal *et al.* (1944), Draize (1944), Orr & Mott (1945), Wilson (1946), Telford & Guthrie (1946), Fitzhugh and Nelson (1947), Ginsburg (1947), Spicer *et al.* (1947), Hagan & Woodard (1948), Woodard & Davidov (1948).

The problem of crop residues and possible translocation of the toxicants into edible plant tissues, which have been treated either by dusting, spraying, or soil treatments, is of primary importance. The question of whether or not sufficient quantities of the toxicants remain as spray residues on fruit, vegetables and forage crops or translocated into the plants so as to constitute a health hazard to the consumer begs a speedy answer, in order to remove the present apprehensive attitude of the farmer, the food processor, and the public in general towards their use.

Considerable knowledge has already accumulated on this subject. Wilson *et al.* (1946) have analyzed pea crops dusted with 3 per cent and 5 per cent DDT at the rate of 30 to 40 pounds per acre. They found from 2 to 6 ppm DDT at harvest on the vines but none in shelled peas. Manulo *et al.* (1946) have analyzed string beans, cabbage, celery, turnips tops, blueberries, grapes, peaches and apples for DDT residues from several spray and dust applications. Variations of DDT from 0.32 to 32 ppm were found on vegetables, while on fruit the residues ranged from 0.05 to 7.12 ppm. In general, the sprays and dusts left varying amounts of residues which did not bear direct quantitative relationships to the number of applications, nor did it decrease proportionately with the length of time elapsing between the last application and harvest.

Liberman (1946) applied 10 per cent DDT dust on seed alfalfa grown in Utah. Samples of alfalfa were analyzed for DDT residues just before and after threshing. No rain, but much drying wind occurred during the 59-day period between treatment and cutting. Three rains totalling about 0.75 inch fell during the 36-day period between cutting and threshing. The results indicated that the DDT residues were not over 17 PPM in the alfalfa before threshing and less than 10 ppm in the chaff after threshing.

Carter (1947) summarizes the results from a cooperative investigation by the U.S.D.A. Bureau of Entomology and Plant Quarantine, Plant Industry, Soils, Agricultural Engineering departments, conducted over two seasons to determine whether vegetable plants would absorb DDT from insecticidal applications and translocate it into the edible portions. The vegetables studied were beans, beets, cabbage, cantaloup, cucumber, onion, peas, potato, squash, tomatoes and turnips that had been treated with dusts and sprays containing DDT. He reports less than 0.5 ppm DDT found in the stripped heads of cabbage, and that the amounts present in the other vegetables were not significant. The results indicate that DDT is not absorbed by vegetables and translocated into the edible portions, following

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station. Rutgers University, Department of Entomology.

Table 1.—DDT residues recovered from alfalfa during 1948.

LOCATION OF PLOTS	TREATMENT DDT	DATES		RAINFALL FROM TREATMENT TO HARVEST	DDT PPM
		Treated	Harvested	Inches	Green Wt.
College Farm					
New Brunswick	3% dust	6/29	7/16	2.59	2.34
"	3% dust	6/29	7/21	2.66	0.00
"	3% dust	6/29	7/26	3.86	0.00
"	3% dust	8/9	9/2	4.16	2.65
"	1% dust impregnated	6/29	7/16	2.59	0.00
"	1% dust impregnated	6/29	7/21	2.66	0.00
"	1% dust impregnated	8/9	9/2	4.16	4.08
Mershon Farm					
Plainsboro	3% dust	6/29	6/29	none	31.90
"	3% dust	6/29	7/20	0.17	0.42
"	1% dust impregnated	6/29	6/29	none	14.46
"	1% dust impregnated	6/29	7/20	0.17	0.97

application to the serial parts of the plants. On the other hand, considerable quantities of DDT were found as residues on some of the plants at harvest. In dried pea vines the author recovered from practically none on some samples to 40 ppm on others, while on forage crops, such as alfalfa and clover, from 2 to 48 ppm were recovered.

Lardy (1948) reports that one application of 3 per cent DDT dust deposited 5 ppm on pea vines. At harvesting time this value was reduced to about one half. No DDT was recovered from the shelled peas or pods, indicating no absorption or translocation.

Eden & Arant (1948) determined DDT residues on alfalfa. One, two, and three treatments with 3 per cent DDT dust were made at 10-day intervals. Samples of foliage were collected immediately after the last application and at 10-day intervals thereafter for 40 days. They report significant amounts of DDT on all alfalfa plots 40 days after dusting. The maximum was 162 ppm on hay harvested immediately after the third dusting at the rate of 30 pounds per acre. The minimum of 10 ppm was present on foliage collected 40 days after one dusting at 15 pounds per acre. All the results were based on oven-dried samples.

Smith *et al.* (1948) have analyzed DDT residues on alfalfa from several localities in California, following dusting and spraying. Straw from alfalfa seed fields, dusted with 5 per cent DDT showed from 0.0 to 20 ppm, even after long weathering periods. Alfalfa hay showed variable amounts of DDT, due to variations in applications, growth of the alfalfa, weathering, and moisture content of the hay. For dust, it ranged from 0.0 to 1.9 ppm at the lowest concentration (0.5 per cent and from 3.7 to 10.3 ppm at the highest concentration (5 per cent). For sprays,

Table 2.—DDT[1] residue recovered from alfalfa in 1947. Averages of several samples from different plots receiving the same treatment.

LOCATION OF PLOTS	TREATMENT DDT	DATES		RAINFALL FROM TREATMENT TO HARVEST	DDT PPM
		Treated	Harvested	Inches	Green Wt.
Mershon Farm	3% dust	4/29	4/29	none	18.0
"	3% dust	4/29	6/2	7.82	0.0
"	3% dust	8/4	8/4	none	34.6
"	3% dust	8/4	8/18	4.02	1.8
"	1% dust impregnated	4/29	4/29	none	11.7
"	1% dust impregnated	4/29	6/2	7.82	0.0
"	1% dust impregnated	8/4	8/4	none	6.6
"	1% dust impregnated	8/4	8/18	4.02	0.6

[1] Chemical analyses were made in the laboratories of Geigy Co.

it ranged from 0.0 to 12.1 ppm, and from 36.4 to 47.2 ppm for 0.25 pound, and 1 pound of actual DDT per acre respectively.

Questel & Connin (1947) grew corn in soil treated with parathion. No injury to plant growth was noticed, but the leaves and stalks were toxic to larvae of the European corn borer. Most of the larvae were killed within 24 hours after hatching on the plants. The authors concluded that parathion or some derivative of it was absorbed by the roots and translocated through the leaves and stalks in sufficient quantities to become toxic to the larvae.

EXPERIMENTAL.—The crops studies in this investigation were alfalfa, corn stalks and kernels, pea vines and shelled peas, and potato tubers. The crops were treated by Filmer and Reed with dusts and spray mixtures of the toxicants for practical insect control on experimental plots and on commercial farms. Representative samples were collected before and during harvest time and, unless otherwise indicated, were analyzed by Ginsburg & Paterson. Only the chemical analyses are reported in this paper. The results are from experiments conducted during the 1948 growing season, with the exception of some of the alfalfa samples on which DDT residues from the 1947 crop, analyzed in the laboratories of Geigy Co., are also included.

CROP TREATMENT.—*Alfalfa.* Alfalfa plots in two widely separated areas were dusted with the following toxicants: 3 per cent DDT, 1 per cent DDT impregnated; 5 per cent methoxychlor; 3 per cent DDD, and 0.5 per cent parathion. On the College Farm in New Brunswick small plots of 25×25 feet were treated employing a rotary hand duster, at the rate of 40 to 45 pounds per acre. On the Mershon Farm at Plainsboro, large areas were dusted by the grower, using 45 pounds of dust per acre applied with a power duster.[1]

At the beginning of the season the plant samples were dried prior to chemical analysis, but later it was discovered that during the drying period, part of the parathion in the residue is lost either by volatility or decomposition, as determined on freshly dusted samples. Whether these losses will be significant in residues analyzed at harvest time, where a period of from 2 to 5 weeks has elapsed from last treatment to date of harvest in the case of alfalfa and pea vines and about 1 to 3 weeks on corn, the writers cannot at present state.

Corn. Samples of corn stalks and ears that had been dusted with 3 per cent DDT, 1 and 0.5 per cent parathion were collected from experimental plots and from a commercial field near Burlington. The experimental plots were treated by hand using bellows dusters with four applications at 5-day intervals being made at the rate of 40 pounds per acre. On the commercial farm, five applications were made with a power duster. The stalks were analyzed for residues and the kernels for translocation of toxicants.

Peas. Separate plots in a field of Thomas Laxton peas grown on the N. J. State Prison Farm at Leesburg were treated with 1 pound DDT; 1 pound and 0.5 pound of parathion per acre, using a tractor drawn power sprayer. The application was made during the first blossom stage at the rate of 100 gallons per acre. Pea vines were analyzed for residues and the shelled peas for translocation of toxicants.[2]

Potatoes. The Katahdin variety of potato was grown in soil treated with varying amounts of parathion. On April 1, a few days before planting, the dust was applied by hand fertilizer spreader at the rate of 5, 10, and 20 pounds of actual parathion per acre. In each case the amount of the toxicant required per plot was mixed with pyrophyllite to make a total volume equivalent to 200 pounds of dust per acre. The soil was disked, harrowed, and cultivated in the usual practice. After harvest, October 12, 1948, several samples of the tubers from each of the treated plots and from the check plots were analyzed for parathion. The first set of samples were run October 23 and the last on December 4.

In order to determine the amounts of parathion still remaining in the soil after harvest, soil samples from the potato plots were analyzed in late October. The soil was a heavy sassafras sandy loam on the College Warnsdorfer Farm.

EXTRACTION OF SAMPLES.—For residue analyses, weighed quantities of the har-

[1] Several samples from the parathion treated alfalfa harvested in the early season, were also analyzed by Dr. P. R. Averell of the American Cyanamid Co.

[2] DDT analyses were determined by Ginsburg & Paterson while the parathion was analyzed by Dr. Averell in the laboratories of the American Cyanamid Co.

Table 3.—DDT recovered from pea vines and shelled peas sprayed with DDT at 1 pound per acre.

Location of Plots	Dates		Rainfall from Treatment to Harvest Inches	DDT-ppm	
	Treated	Harvested		Pea Vines Green Wt.	Shelled Peas Dry Wt.
Leesburg State Prison Farm	5/28	6/21	4.40	3.22	
"	5/28	6/29	5.43	0.42	
"	5/28	6/29	5.43		0.41

vested plants were dried in a shaded greenhouse for about 4 or 5 days, or until most of the moisture content had evaporated. The dry material was again weighed and samples equivalent to one pound of green weight were extracted with 750 to 1000 ml. benzene, depending on the bulkiness of the sample, by shaking for about 40 minutes to 1 hour. The solvent was then filtered and aliquots of 100 to 200 ml. were analyzed for the toxicants.

A somewhat different procedure was employed in processing plant tissues for determining the translocation of toxicants. Corn kernels were shelled from dried ears, finely ground, and 100 gm. samples were extracted in 250 ml. benzene for 48 hours with frequent shaking. The benzene was then filtered and analyzed. The peas were shelled soon after harvest and dried in the laboratory at about 80° F., a fan being used to provide ample air circulation. They were then finely ground and extracted with benzene using the same procedure as with the corn kernels. In shelling the peas and corn, precautions were taken to eliminate contamination from pods, husks, etc.

The tubers were washed with water to remove soil and other impurities, dried with cheesecloth, peeled and ground in a meat chopper. Five hundred gm. samples of the freshly ground material were extracted with 1 liter of benzene by continuous shaking for about 1 hour. During this procedure the benzene became emulsified and had to be separated by centrifuging. The supernatant solvent was then filtered and about 200 ml. aliquots were used for each analysis.

The soil was processed as follows: 500 gm. samples of fresh soil were extracted with 1000 ml. benzene by shaking for about 1 hour, filtered and 200 ml. aliquots used for analyses. No emulsification was encountered with this type of soil.

CHEMICAL ANALYSES.—The total organic chlorine method described in The Journal of the Association of Official Agricultural Chemists (1947), was used for determining DDT, dichlorodiphenyl dichloroethane, and methoxychlor. In several instances the colorimetric method developed by Schlechter (1945) and later modified by Wichmann *et al.* (1946) was also employed in determining DDT. The total chlorine method was used since it is

Table 4.—DDT recovered from corn stalks and kernels.

Location of Plots	Variety of Corn	Treatment DDT	Dates		Rainfall from Treatment to Harvest Inches	DDT-ppm	
			Treated	Harvested		Stalks Green Wt.	Kernels Dry Wt.
Bonnewitz Farm	Marcross 13–6 hybrid	3% dust applied 4 times by hand duster	6/18 6/23 6/28 7/3	7/22	6/18–7/3=4.19 7/4–7/22=1.72	0.40	0.0
Stockoff Farm	Golden Cross Bantam	3% dust applied 4 times by hand duster	8/11 8/16 8/21 8/26	9/3	8/11–8/26=5.56 8/26– 9/3=0	18.40	0.0
Johnson Farm	North Star	3% dust applied 5 times by power duster	—	7/15	—	0.32	—

Table 5.—Dichlorodiphenyl dichloroethane residues recovered from alfalfa.

Location of Plots	Treatment	Dates		Rainfall Treatment to Harvest	Dichlorodiphenyl Dichloroethane ppm
		Treated	Harvested	Inches	Green Wt.
College Farm	Dichlorodiphenyl dichloroethane 3% dust	6/29	7/21	2.66	0.00
"	Dichlorodiphenyl dichloroethane 3% dust	6/29	7/26	3.86	0.32
Mershon Farm	Dichlorodiphenyl dichloroethane 3% dust	6/~~30~~	6/29	none	19.30
"	Dichlorodiphenyl dichloroethane 3% dust	6/29	7/26	2.18	0.32

applicable to each one of the three toxicants.

With each harvest, check plants taken from untreated plots, were also analyzed. The chlorine found in the checks was subtracted from that recovered in the treated plants. The difference was calculated in ppm of the chlorinated toxicant. Blanks, consisting of the reagents only, were used with each series of analyses in order to eliminate possible impurities from the calculations.

Parathion. The colorimetric method developed by Averell & Norris (1948) was used for determining parathion. The principal steps in this method consist of the following: (a) Extraction of the sample with benzene; (b) Evaporation of the solvent to dryness; (c) Reduction of the extracted residue in HCl solution with zinc to the amine compound, diethyl *p*-aminophenyl thiophosphate; (d) Diazotization of the amino compound with sodium nitrite; (e) Removal of excess nitrite with ammonium sulfamate; (f) Developing the magenta color with *N*-(1-Naphthyl)-ethylenediamine dihydrochloride; (g) Evaluation of the color on a photocolorimeter or spectrophotometer in comparison with a standard transmittance—concentration curve, prepared from known quantities of pure parathion. This compound has an absorption maximum on the spectrophotometer at about 555 mμ. According to Averell, a green filter with a transmittance peak of 520 mμ gave a satisfactory transmittance gradient. In our laboratory a green filter with a transmittance peak of 525 mμ on the Fisher electrophotometer was employed.

This method is very sensitive, detecting as low as 0.01 ppm parathion. However, a certain amount of magenta color is also formed with the check plant material and even in the blanks although the purest reagents obtainable and thiophene-free benzene were used. It was therefore, necessary to run blanks with each series of determinations and with each batch of benzene. The per cent transmittance readings for the blanks were subtracted from the treated as well as from check samples.

Duplicate aliquots from each extract were analyzed. In many instances two or more samples were extracted giving averages of several determinations for one treatment. The rainfall during the

Table 6.—Methoxychlor residues recovered from alfalfa.

Location of Plots	Treatment Methoxychlor	Dates		Rainfall from Treatment to Harvest	Methoxychlor ppm
		Treated	Harvested	Inches	Green Wt.
College Farm	5% dust	5/1	6/10	7.01	3.35
"	5% dust	6/29	7/16	2.59	3.50
"	5% dust	6/29	7/21	2.66	0.00
"	5% dust	8/9	9/2	4.16	2.65
Mershon Farm	5% dust	6/29	6/29	none	54.10
"	5% dust	6/29	7/26	2.18	0.00

Table 7.—Parathion recovered from dust residues on alfalfa.

LOCATION OF PLOTS	PARATHION TREATMENT	DATES		RAINFALL, TREATMENT TO HARVEST	PARATHION PPM
		Treated	Harvested	Inches	Green Wt.
College Farm	0.5% hand dusted	5/1	6/9	7.21	0.06
"	0.5% hand dusted	5/1	6/2	10.16	0.02
Mershon Farm	0.5% power dusted	5/1	6/20	11.83	0.04
College Farm	0.5% hand dusted	6/29	7/13	1.10	0.12
"	0.5% hand dusted	8/9	8/9	none	0.53
"	0.5% hand dusted	8/9	8/18	0.81	0.06
Mershon Farm	0.5% power dusted	7/1	7/12	0.17	0.06

Samples harvested six-ninths, seven-twelfths and seven-thirteenths were analyzed by Dr. P. R. Averell in the laboratories of the American Cyanamid Co.

periods from insecticide application to harvest were figured from records of official stations located at or near the areas where the crops were grown.

RESULTS.—In tables 1 to 12 inclusive, the data from the chemical analyses, dates of treatment and harvest, kinds and quantities of insecticides applied, location where crops were raised, plant varieties and accumulated rainfall from treatment to harvest are given. A study of the tables brings out the following information.

RECOVERY OF DDT.—*Alfalfa.* From the data in Tables 1 and 2 the following items are significant. The initial deposits of DDT varied from 18 to 34.6 PPM for the 3 per cent dust and from 11.7 to 14.46 ppm for the 1 per cent impregnated dust. Apparently the impregnated dust had deposited proportionately larger amounts of DDT, based on the original DDT content, than did the 3 per cent dust. However, DDT residues recovered at harvest were in general somewhat higher for the 3 per cent dust, ranging from none to 4.18 ppm as compared with 0 to 0.97 ppm for the 1 per cent impregnated dust.

DDT on Peas. Of the sprayed pea vines analyzed (Table 3) one sample harvested June 21 gave 3.22 ppm and another sample from the same plot harvested on June 29 had only 0.42 ppm DDT, the accumulated rainfall being 4.4 and 5.43 inches for the two dates respectively. The higher amount of rainfall may account for the lower deposit recovered from the second sample, although the increase in plant growth of which no record was available, should also be considered. The sample of shelled peas harvested from the same crop on June 29 gave an average of 0.4 ppm DDT, determined by both, total chlorine and colorimetric method.

DDT on Corn. No DDT was found in kernels from two varieties of corn dusted 4 times with 3 per cent DDT. Stalks from three varieties of corn, dusted with 3 per cent DDT were analyzed at harvest (Table 4). The Marcross 13–6 hybrid, treated 4 times by hand duster, and North Star treated 5 times by power duster showed only 0.4 and 0.32 ppm of DDT respectively. On the other hand, Golden Cross Bantam dusted 4 times gave 18.4 PPM. Examination of the rainfall records shows that in the case of the Marcross 13–6, 1.72 inches of rain fell between the last dust application and the harvest date, while in the case of the Golden Cross Bantam no rain fell during the period between the last application and harvest.

These differences suggest the possible danger involved in using DDT-dusted corn stalks either as green fodder or for silage when harvested during drought, or at least in the absence of sufficient rainfall to wash off the residue from the last application.

Table 8.—Parathion recovered from freshly dusted and dried samples of alfalfa.

LOCATION OF PLOTS	PARATHION APPLICATION	DATES		PARATHION PPM
		Treated and Harvested	Analyzed	Green Wt.
College Farm	0.5% dust heavy application	8/23	8/23	20.40
College Farm	0.5% dust heavy application	8/23	8/27	7.72

DICHLORODIPHENYL DICHLOROETHANE RECOVERY.—Two crops of alfalfa (Table 5), dusted once with 3 per cent DDD were analyzed. No appreciable differences in the residues appeared between the hand-dusted and power-dusted plots. Alfalfa from the college farm had 0 to 0.32 ppm of DDD, while samples from the Mer-

Table 9.—Parathion recovered from corn kernels.

Location of Plots	Corn Variety	Parathion Applied 4 Times	Dates		Parathion ppm Dry Wt.
			Treated	Harvested	
Bonnewitz Farm	Marcross 13–6 hybrid	1% dust	6/18 6/23 6/28 7/3	7/22	0.05
Bonnewitz Farm	Marcross 13–6 hybrid	0.5% dust	7/3	7/22	0.07
Stockoff Farm	Golden Cross Bantam	1% dust	8/11 8/16 8/21 8/26	9/3	0.00

shon farm averaged 0.32 ppm at harvest, although the initial deposit was 19.3 ppm.

RECOVERY OF METHOXYCHLOR.—Four alfalfa crops, dusted once with 5 per cent methoxychlor were analyzed (Table 6). On the college farm, where a hand-duster was employed the residue contained from 0 to 3.5 ppm of toxicant. The alfalfa from the Mershon Farm, treated by power-duster showed no presence of toxicant at harvest, although an initial deposit of 54.1 ppm was recovered on June 29 the day when the dust was applied.

RECOVERY OF PARATHION.—*Alfalfa.* Samples from five crops dusted once with 0.5 per cent parathion were analyzed. The results (Table 7) show variations in the residues from 0.02 to 0.12 ppm parathion. The surprising factor in this table was that a sample from the plot dusted and harvested on the same day namely, August 9, but analyzed after drying, showed deposits of only 0.53 PPM parathion. It was suspected that the effect of drying before the analysis may be responsible for the low amounts of parathion recovered. In order to verify this assumption, a plot of alfalfa on the college farm was heavily dusted with 0.5 per cent parathion on August 23. One sample was harvested soon after dusting and analyzed on the same day. Another sample harvested at the same time was dried in the greenhouse for 4 days by the usual procedure and analyzed. The results (Table 8) indicate 20.4 ppm parathion in the green sample and only 7.72 ppm in the dried sample, a reduction of about 62 per cent. Apparently exposure of the dusted plants to atmospheric conditions bring about decomposition, volatilization or both of the parathion. Probably for the same reason low initial deposits, 3.2 and 1.7 ppm were also obtained on two other plots dusted and sampled on August 10, but dried for six days and analyzed August 16. Whether or not the same process takes place in the field where the plants are continuously exposed to sunlight, resulting in the rapid decomposition of the toxicant will require further study, However, the low quantities of parathion residues found in all the harvested crops analyzed in this investigation certainly indicate it.

Parathion in Corn. Three samples of corn kernels from plants dusted four times with either 0.5 per cent or 1 per cent parathion (Table 9) showed insignificant quantities of toxicant, ranging from 0 to .07 ppm. The ppm parathion recovered in the residues from two samples of dusted corn stalks (Table 10) were .02 for the 0.5 per cent and 0.13 for the 1 per cent dust.

Parathion in Peas. Five samples of

Table 10.—Parathion recovered from corn stalks, Marcross 13–6 hybrid.

Location of Plots	Parathion Applied 4 Times	Dates		Rainfall, Treatment to Harvest Inches	Parathion ppm Green Wt.
		Treated	Harvested		
Bonnewitz Farm	1% dust	June 18 June 23 June 28 July 3	July 22	5.93	0.13
Bonnewitz Farm	0.5% dust	July 3	July 22	5.93	0.02

Table 11.—Parathion[1] recovered from shelled peas (Thomas Laxton).

Location of Plots	Parathion Application	Dates		Rainfall, Treatment to Harvest	Parathion ppm
		Treated	Harvested	Inches	Green Wt.
Leesburg State Prison Farm	1% dust	June 2	June 29	3.54	0.03
"	0.5% dust	June 2	June 29	3.54	0.02
"	Spray 1 lb/acre	May 28	June 29	5.43	0.00
"	Spray 0.5 lb/acre	May 28	June 29	5.43	0.00
"	Spray 0.25 lb/acre	May 28	June 29	5.43	0.00

[1] Chemical analyses made by Dr. P. R. Averell in the American Cyanamid Laboratories.

shelled peas as recorded in Table 11, show negligible quantities of parathion, indicating no translocation of the toxicant. Peas from the three sprayed plots contained no parathion. Peas from two plots receiving 0.5 per cent and 1 per cent dust showed .02 and .03 ppm parathion respectively, which may well be within the experimental error. The pea vines from which the shelled peas described in Table 11 were collected, showed no parathion residues at harvest. They were analyzed by Dr. Averell in the laboratories of the American Cyanamid Co.

Parathion in Potato Tubers. The potatoes were harvested October 12 and placed in storage. Only one sample of tubers from the plot treated with 5 lbs. of toxicant per acre was available. Analysis on November 17 showed no parathion. Tubers from the 10 and 20 lbs. treated soils were first analyzed October 23, showing 0.097 and 0.145 ppm (Table 12) parathion respectively. Subsequent analyses made December 1 and December 4 gave varying results, ranging from .05 to .17 ppm in the 10 lbs. treated plots, and from none to .15 ppm on the 20 lbs. treated plots. While these variations cannot be fully explained, several possibilities may be considered. Tubers from different parts of the plots did not absorb equal amounts of parathion either due to unequal distribution in the soil or to some other factors. Parathion decomposes in the tubers during storage. Organic substances present in the tubers may interfere with the accuracy of the chemical method.

Parathion in Soil. Samples from soil plots treated with 10 and 20 lbs. parathion per acre were taken October 28 and analyzed October 29. The soil from the 5 lbs. treatment was sampled November 11 and analyzed November 17. The results given in Table 12, show no parathion in the soil treated with 5 lbs. per acre. 0.37 and 1.2 ppm in the 10 and 20 lb. treated soils respectively. Assuming that the 20 lbs. were incorporated in the top 6 inches of soil, weighing about 2,000,000 lbs., the parathion added would equal 10 ppm. The recovery on this plot would, therefore, equal about 12 per cent 7 months after application.

SUMMARY AND CONCLUSIONS.—Chemical analyses of four of the newer insecticides, namely DDT, dichlorodiphenyl dichloroethane, methoxychlor, and parathion, were made on several sprayed and dusted vegetable corps in order to study the residues of the toxicants and their possible translocation or absorption into edible plant tissues at harvest time. The crops were raised in the field either in experimental plots or on commercial

Table 12.—Parathion recovered from treated soil and potato tubers grown in it.

Location of Plots	Parathion Application Per Acre	Dates		Rainfall from Treatment to Harvest	Parathion ppm	
		Treated	Sampled	Inches	Tubers	Soil
Warnsdorfer Farm New Brunswick	5 lbs	April 1	October 12	31.0	0.00	0.00
"	10 lbs	April 1	October 12	31.0	0.097	0.37
"	20 lbs	April 1	October 12	31.0	0.147	1.20

farms. The insecticides were applied for practical insect control, but only the results from the chemical analyses are discussed here. Samples of the plants were collected, before and during harvest, dried in a shaded greenhouse, and extracted with benzene. The solvent was evaporated and the residue analyzed for the toxicants.

DDT residues were determined on alfalfa treated with 3 per cent and 1 per cent DDT dusts, on corn stalks dusted 4 or 5 times with 3 per cent DDT, and on pea vines sprayed at the first blossom stage with one pound DDT per acre. Residues of DDD and methoxychlor were analyzed on alfalfa dusted with 3 per cent and 5 per cent of the two toxicants respectively. Parathion residues were determined on pea vines, corn stalks and alfalfa. Shelled peas and corn kernels were analyzed for translocation of DDT and parathion. Absorption of parathion was also determined in potato tubers grown on soil treated with 5, 10, and 20 pounds parathion per acre.

The results brought out the following information. Residues from the three chlorinated insecticides on all crops tested, contained from none to 4 PPM of toxicants based on green weight. In general, higher amounts of toxicants were found on alfalfa than on corn stalks and pea vines. While the amount of rainfall played a definite role on the quantities of toxicants recovered at harvest, the relationships were not always proportional. Evidently other factors such as plant growth, variety, etc, are contributing items. However, in the absence of rainfall high deposits (19 ppm) of DDT were recovered from dusted corn stalks.

About 0.4 ppm of DDT was found in one sample of shelled peas from plants sprayed at the blossom stage with 1 pound of DDT per acre. No DDT was present in corn kernels from plants dusted four times with 3 per cent DDT.

Parathion residues at harvest were in general, very low on all crops tested, regardless of treatment, ranging from none to 0.13 ppm. Negligible quantities of parathion were recovered from corn kernels and shelled peas, indicating no translocation.

Parathion deposits on plants decompose during the drying process, prior to chemical analysis. For accurate values of this toxicant, the plants should be analyzed fresh, soon after harvest.

Potato tubers from soil treated with 10 and 20 lbs. parathion per acre contained small quantities of parathion when analyzed soon after they were dug.

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Comparative Toxicity to Certain Insects of DDT, Its Bromine and Fluorine Analogs, and Gamma Benzene Hexachloride

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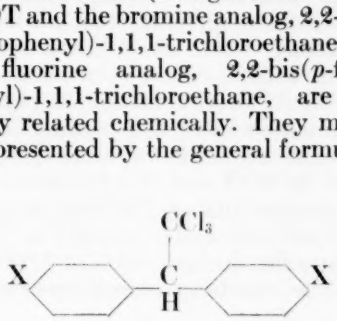
Preliminary toxicity tests made with dusts of both the bromine and fluorine analogs of DDT indicated that these compounds had appreciable insecticidal value. The fluorine analog was used rather extensively by the Germans as an all-purpose insecticide during the war years (Kilgore 1945).

It was therefore considered important to make a comparison of the toxicity of these insecticides. The bromine analog was included largely because high kills had been obtained in preliminary tests with this chemical (Bottger & Levin 1947)

DDT and the bromine analog, 2,2-bis(*p*-bromophenyl)-1,1,1-trichloroethane, and the fluorine analog, 2,2-bis(*p*-fluorophenyl)-1,1,1-trichloroethane, are very closely related chemically. They may all be represented by the general formula



in which X represents F, Cl, or Br. They were prepared by condensing fluorobenzene, chlorobenzene, or bromobenzene with chloral. They are all colorless solids. The samples tested had the following melting points: DDT 108°, fluorine analog 45°, and bromine analog 144° C.

The comparative toxicity of gamma benzene hexachloride and DDT to ten species of insects was reported by Bottger and Levin (1946). Comparisons of the insecticidal action of DDT and the fluorine analog have been reported by Martin and Wain (1944), Proverbs & Morrison (1947), Muller (1946), Domenjoz (1946), Deonier *et al.* (1946), Busvine (1946), Prill *et al.* (1946), and Metcalf (1948). Gamma benzene hexachloride was reported to be more toxic than DDT to 8 of 10 species tested, about equally toxic to the variegated cutworm, *Peridroma margaritosa* (Haw.), and less toxic to the celery leaf tier, *Phlyctaenia rubigalis* (Guen.). In general, the toxicity of the fluorine analog was about equal to that of DDT but less than that of gamma benzene hexachloride.

Table 1.—Comparative toxicity of gamma benzene hexachloride, DDT and the fluorine and bromine analogs of DDT to third-instar larvae of the armyworm.

Insecticide	Deposit per Square Centimeter	Mortality in 48 Hours	
	Micrograms	*Per Cent*	
Gamma benzene hexachloride	0.125	32	
	.1875	64	
	.25	73	
		Average	56
DDT	.25	22	
	.375	58	
	.5	84	
		Average	55
Fluorine analog	.25	31	
	.375	56	
	.5	90	
		Average	59
Bromine analog	5.00	20	
	7.50	34	
	10.00	38	
		Average	31

Therefore gamma benzene hexachloride was included in these tests.

For the comparisons of toxicities herein reported the compounds were tested in the laboratory against five species of insects. The toxicants, diluted in pyrophyllite, were applied as dusts to both surfaces of foliage for testing against insects with chewing mouth parts and directly on the body surfaces of the sucking insects. The dusts were applied in a settling chamber, and the amount of deposit was determined by dusting and weighing an aluminum plate at the same application.

Tests Against the Armyworm.—An extensive study was made of the effectiveness of the three related compounds and gamma benzene hexachloride against third-instar larvae of the armyworm, *Cirphis unipuncta* (Haw.). Preliminary tests were made to determine dosages necessary to kill roughly 25, 50, and 75 per cent of the insects. All tests were replicated five times. Mortality counts were made approximately 48 hours after treatment. The results of these tests are presented in table 1.

At the lowest concentrations tested against the armyworm, the fluorine analog appears to be approximately 50 per cent more toxic than DDT and over 20 times as toxic as the bromine analog. However, at the intermediate and high levels no significant difference between DDT and its fluorine analog is indicated, and both compounds effected kills not significantly higher than resulted from 20 times greater deposits of the bromine analog. Considering mortalities effected at all three levels, the fluorine analog appears to be about one-half as toxic as gamma benzene hexachloride.

There are no significant differences in the mean mortalities resulting from deposits of 0.125 microgram per square centimeter of gamma benzene hexachloride and 0.25 microgram of DDT or the fluorine analog. Therefore, the effectiveness of these materials may be compared on the basis of the dosages employed. It was found by plotting on log-probit paper that the median lethal dose for third-instar armyworm larvae is 0.16 microgram per square centimeter of leaf surface for gamma benzene hexachloride, 0.33 microgram for the fluorine analog, and 0.35 microgram for DDT. The mortality curves are shown in figure 1. On the basis of 50-per cent mortality values, gamma benzene hexachloride is 2.0 times and the fluorine analog 1.09 times more toxic than DDT. The average mortality resulting from treatments of the bromine analog of DDT employed at a dosage of 5 micrograms per square centimeter is significantly lower than the average mortalities resulting from treatments of 0.125 microgram per square centimeter of gamma benzene hexachloride or 0.25 microgram per square centimeter of the fluorine analog and DDT. These data indicate the toxicity of gamma benzene hexachloride, DDT, and the fluorine analog against the armyworm to be more than 40, 20, and 20 times, respectively, greater than that of the bromine analog.

Tests Against Pea Aphid.—Three-day-old nymphs of the pea aphid, *Macrosiphum pisi* (Kltb.), on Windsor bean plants were dusted with 0.5, 1, 4, and 10 micrograms per square centimeter of each insecticide. Twenty-four hours after treatment, average mortalities of 3 replications were as follows: gamma benzene hexachloride 97 per cent, DDT 60 per cent, fluorine analog 50 per cent, and bromine analog 23 per cent. Gamma benzene hexachloride was more than twice as toxic as DDT and over 8 times as toxic as the fluorine analog. The bromine analog showed no appreciable toxicity at 10 and 20 times the dosages used of DDT and gamma benzene hexachloride, respectively.

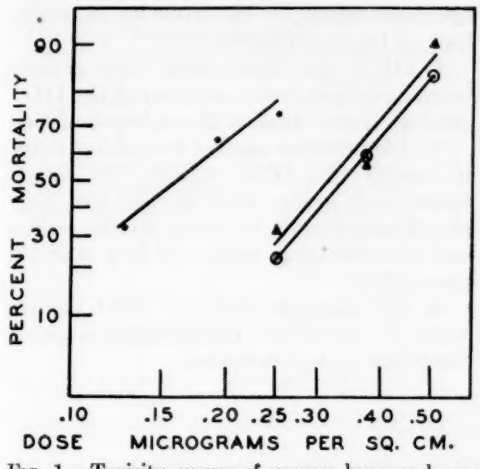


FIG. 1.—Toxicity curves of gamma benzene hexachloride, DDT, and its fluorine analog applied as dusts against third-instar larvae of the armyworm, plotted on log-probit paper.
● = gamma benzene hexachloride, ▲ = fluorine analog of DDT, ⊙ = DDT.

A total of 78 to 101 insects were used in the two replications in each test.

TESTS AGAINST THE GREEN DOCK BEETLE.—Smooth dock leaves were dusted and placed in petri dishes with 24 third-instar larvae of the green dock beetle, *Gastroidea cyanea* (Melsh.), for each test which was replicated twice. Average larval mortalities after a 3-day test period are presented in table 2.

The gamma benzene hexachloride dosage was too high here, resulting in 100 per cent mortality. However, the results indicate the same order of toxicity as in previous cases. While still the least toxic of the four materials, the bromine analog was effective against this insect when employed at a dosage only twice as great as that of the other toxicants.

TESTS AGAINST CELERY LEAF TIER.—The third-instar larvae of the celery leaf tier, *Phlyctaenia rubigalis* (Guen.) were tested by placing them in petri dishes with dusted sections of Swiss chard leaves. DDT was the most effective toxicant against this insect. Gamma benzene hexachloride and the fluorine analog exhibited about equal toxicity, being about one-fourth as toxic as DDT but some seven and one-half times as toxic as the bromine analog. Treatments and results appear in table 2. Twenty-four larvae were used in each test which was replicated three or more times.

TESTS AGAINST THE LARGE MILKWEED BUG.—Third-instar nymphs of the large milkweed bug, *Oncopeltus fasciatus* (Dall.) were placed in glass crystallizing dishes and dusted in a settling chamber. Untreated food and water were supplied during the 2-day test period. Twenty insects were used in each test which was replicated three times. Gamma benzene hexachloride was much more toxic than DDT or either the bromine or the fluorine analog. The same strengths of DDT and its fluorine analog resulted in average mortalities of 58 and 15 per cent, respectively. The bromine analog was less than one-fifth as toxic as DDT and about half as toxic as the fluorine analog.

Table 2.—Comparative toxicity of gamma benzene hexachloride, DDT, and the fluorine and bromine analogs of DDT to certain insects.

INSECTICIDE	INSECT	DEPOSIT OF INSECTICIDE PER SQUARE CENTIMETER	MORTALITY IN	
			2 Days	3 Days
		Micrograms	*Per Cent*	*Per Cent*
Gamma benzene hexachloride	Green dock beetle	1.00	—	100
	Celery leaf tier	1.00	39	—
	Large milkweed bug	0.13	81	—
DDT	Green dock beetle	1.00	—	92
	Celery leaf tier	0.25	31	—
	Large milkweed bug	2.30	58	—
Fluorine analog	Green dock beetle	1.15	—	83
	Celery leaf tier	1.00	38	—
	Large milkweed bug	11.50	85	—
Bromine analog	Green dock beetle	2.30	—	71
	Celery leaf tier	7.50	31	—
	Large milkweed bug	11.50	43	—

SUMMARY.—The insecticidal effectiveness of DDT, its bromine and fluorine analogs, and gamma benzene hexachloride has been tested in the laboratory against five insects. Tests were made against the armyworm, *Cirphis unipuncta* (Haw.), celery leaf tier, *Phlyctaenia rubigalis* (Guen.), the large milkweed bug, *Oncopeltus fasciatus* (Dall.), the pea aphid, *Macrosiphum pisi* (Kltb.) and the green dock beetle, *Gastroidea cyanea* (Melsh.). The following evaluations have been made of the data presented:

1. Gamma benzene hexachloride was considerably more toxic than DDT, the bromine analog, or the fluorine analog to four of the five insects.

2. DDT was more toxic than gamma benzene hexachloride or either of the DDT analogs tested against the celery leaf tier.

3. The fluorine analog was about equal in toxicity to DDT against the armyworm and green dock beetle; but only about one-fourth as toxic to the celery leaf tier, the large milkweed bug, and the pea aphid.

4. The bromine analog of DDT showed very low toxicity in comparison to any of the other toxicants tested.

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Phytotoxicity and Off-Quality of Vegetables Grown in Soil Treated with Insecticides[1]

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Development of new insecticides has been extremely rapid during recent years. The use of these new products has raised many questions in the minds of workers, *i.e.:* do they injure certain vegetables; are they causing an off-flavor or reduced quality; will the residues in the soil be a harmful problem; and will the insects build up a rapid resistance or tolerance to the insecticides?

Plant injury by insecticides is not a new problem. Each new insecticide is potentially injurious to some species of plants. One of the new and most important problems confronting us in evaluating new insecticides is their effect upon the quality or flavor of vegetables. Benzene hexachloride has been found to cause off-flavor in certain vegetables. O'Kane (1947), reported objectionable flavor in potatoes, peas, and sweet corn that had been treated with benzene hexachloride. Greenwood (1947), Pepper *et al.* (1947) Wolfenbarger (1948) and Wolfenbarger *et al.* (1948) Webster (1948) reported that definite off-flavors were detected in potatoes grown in soil treated with benzene hexachloride. Lamb,[4] observed off-flavor resulting from benzene hexachloride treatments in processed lima beans, sliced car-

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[4] Unpublished data.

Table 1.—Mean number of plants (stand counts) from 5 randomized plots grown in Sultan loam at Puyallup, Washington—1948.

TREATMENT	AMOUNT PER ACRE	BUSH BEANS	BEETS	CAULIFLOWER	SWISS CHARD	TURNIPS
	Pounds	*Number*	*Number*	*Number*	*Number*	*Number*
Benzene[1] hexachloride	0.5 Gamma	63	27	184	58	30
Benzene[1] hexachloride	2 Gamma	46	13	155	31	22
Benzene[2] hexachloride	0.5 Gamma	69	45	182	62	48
Benzene[2] hexachloride	2 Gamma	62	36	229	62	35
Parathion	0.5 Actual	58	35	204	79	50
Parathion	2 Actual	35	19	115	35	24
Chlordan	5 Actual	70	36	—	57	42
Chlordan	34.8 Actual	55	29	176	51	33
Untreated Check		76	33	192	63	58
Difference required for Significance (5 per cent level)		13.4	12.2	51.3	18.2	17.8
Difference required for Significance (1 per cent level)		20.7	16.4	69.3	24.5	24.0

[1] Benzene hexachloride.
[2] High gamma formulation of benzene hexachloride.

rots, spinach, tomatoes and tomato juice. A musty off-flavor or odor was detected in many samples of canned peaches when they had been sprayed with benzene hexachloride approximately 60 days before harvest. (Davis 1948.)

In evaluating the phytotoxicity and effect on quality or flavor, four insecticides were applied to the soil surface and 10 vegetables were planted in the treated soil in June 1948. Data were taken on stand count, yield, and flavor of some of the vegetables.

MATERIALS AND METHODS.—Insecticide dusts used in the studies were: 1 per cent gamma isomer of benzene hexachloride, 1 per cent gamma isomer of the high gamma type benzene hexachloride, 1 per cent parathion, and 5 per cent chlordan. The high gamma type benzene hexachloride was formulated from an approximately 99 per cent gamma isomer concentrate; whereas the other benzene hexachloride product was formulated from the 37 per cent gamma material. Rates of application on the acre basis were: ½ and 2 pounds gamma of both the benzene hexachloride and the high gamma type benzene hexachloride, ½ and 2 pounds actual paration, and 5 and 34.8 pounds actual chlordan. These materials were sifted on to the surface of the soil.

Vegetables and varieties[1] used in these tests were: Blue Lake pole beans; Stringless Green Pod bush beans; Detroit Dark Red Morse's Strain beets; Chantenany Red Cored carrots; Early Snowball A cauliflower; Cubit cucumbers; Sweet Spanish Yellow onions; Golden Delicious squash; and Lucullus Swiss chard.

The seeds were planted with a *Planet Jr.* hand seeder on June 7 and 8 within one day after the insecticide was applied to the soil surface.

Each treatment was replicated 5 times in randomized plots 10 by 30 feet. Soil type in the plots was Sultan loam with a pH 6.0. A fertilizer (ammonium phosphate, 11–48, 600 pounds per acre) was applied as a side dressing after the vegetables were from 1 to 3 inches tall.

RESULTS.—*Plant Counts of Seedlings:* Plant counts were taken to determine if the insecticide treatment had any injurious effect on the vegetable seedlings. Counts on 3 feet of center of row of bush beans, cucumbers, and pole beans were taken on June 22, 14 days after planting the seed. Analyses of variance of stand counts of cucumbers were computed. Reduction in numbers of cucumber plants in the different treatments when compared with the untreated check were highly significant at 2 pounds gamma benzene hexachloride, 2 pounds actual parathion, and 34.8 pounds actual chlordan, and significant in the 2 pounds gamma of the high gamma type benzene hexachloride.

PLANT COUNT AT HARVEST.—Plant counts were taken at the completion of harvest in all vegetable plots, with the exception of peas. Analyses of variance

[1] Seeds furnished by Ferry-Morse Seed Company, San Francisco 24, Calif.

of stand counts were computed and significant differences were found between stands of the different treatments for bush beans, beets, cauliflower, Swiss chard, and turnips. The data are shown in table 1. Significant differences were not found for pole beans, carrots, cucumbers, onions, and squash.

Benzene hexachloride, 2 pounds gamma isomer, reduced plant stands at highly significant levels for bush beans, beets, Swiss chard, and turnips, when compared with the untreated check. A one-half pound treatment of the gamma isomer caused a highly significant reduction of the turnip stands. The benzene hexachloride formulated from the high gamma product was less phytotoxic to the vegetables tested than the regular type benzene hexachloride. Only bush beans and turnips stands were significantly reduced in the 2 pound gamma treatment; whereas, the one-half gamma caused no reduction in plant stands. Parathion, 0.5 pound actual, caused a significant reduction of bush beans. The treatment using 2 pounds actual parathion reduced the plant stands at highly significant levels for bush beans, beets, cauliflower, Swiss chard, and turnips. Chlordan, applied at 5 pounds actual, caused no significant decrease in the plant stands, but the high application of chlordan, 34.8 pounds actual, resulted in a highly significant stand reduction for bush beans and turnips.

SAMPLING FRESH VEGETABLES FOR FLAVOR OR QUALITY.—Preliminary investigations in 1948 indicated that soil treatments with certain organic insecticides caused apparent off-flavor or reduced quality of some vegetables. Fresh samples of bush beans, pole beans, carrots, cucumbers, and peas were tasted for off-flavor or reduced quality by 5 to 17 individuals; the taste panels varied for each different vegetable examined. A summary of the results of the taste panels is tabulated in table 2.

Reactions reported by the panel from the treatments were: putrid, bitter, stings tongue, and musty. Taste responses for fresh vegetables which were grown in soil treated with parathion, chlordan, and in some cases, the high gamma benzene hexachloride were: flat, not as sweet as check, and starchy. Peas and pole beans showed definite differences between untreated checks and treatments; whereas, the differences between treatments for bush beans, carrots, and cucumbers were not as marked.

Individuals assisting in the taste panel were not professional tasters, but probably represented a fair cross-section of consumers of vegetables. It was evident that marked variations occurred between the responses of the taste buds of different individuals. It was evident from these observations that trained individuals would probably detect off-flavor or reduced quality more often than inexperienced individuals.

Vegetables from plots treated with benzene hexachloride which were prepared, either by canning or freezing, may

Table 2.—Number of samples were off-flavor or reduced quality was detected.

TREATMENTS	AMOUNT PER ACRE	BUSH BEANS	POLE BEANS	CARROTS	CUCUMBERS	PEAS
	Pounds	*Number*	*Number*	*Number*	*Number*	*Number*
1 Benzene hexachloride	0.5 Gamma	7	3	6	4	10
2 Benzene hexachloride	2 Gamma	5	5	3	4	12
3 Benzene hexachloride[1]	0.5 Gamma	8	3	4	2	3
4 Benzene hexachloride	2 Gamma	4	4	7	6	5
5 Parathion	0.5 Actual	4	1	4	1	4
6 Parathion	2 Actual	5	2	5	6	8
7 Chlordan	5 Actual	8	2	3	3	2
8 Chlordan	34.8 Actual	5	1	3	2	6
9 Untreated Check		3	0	2	4	1
No. of samplings taken in each crop treatment		12	5	9	8	17

[1] A high gamma formulation of benzene hexachloride.

when opened at a later date for consumption, show a greater degree of off-flavor than the fresh or freshly processed vegetables. In one test in 1947, carrots that were grown in plots treated with benzene hexachloride and canned could not be used because a very strong offensive odor was detected when the cans were opened; whereas, the fresh carrots were considered to be excellent in taste and quality. In another test, fresh beans, broccoli, cauliflower, and corn grown in the soil treated with 2 pounds gamma per acre of either benzene hexachloride or high gamma benzene hexachloride in 1948 showed no consistent off-flavor before processing. These same vegetables were processed and checked at a later date and the off-flavor or odor, or both, were definitely detected.

SUMMARY.—Benzene hexachloride, 0.5 and 2 pounds gamma; benzene hexachloride fromulated from high gamma benzene hexachloride, 0.5 and 2 pounds gamma; parathion, 0.5 and 2 pounds actual; and chlordan, 5 and 34.8 pounds actual; per acre, were applied to the soil surface in randomized plots. Bush beans, pole beans, beets, carrots, cauliflower, cucumbers, onions, squash, and Swiss chard were planted in the plots within 1 day after the insecticide treatment.

Reductions in stands of cucumber seedlings, 14 days after planting, were highly significant for treatments of 2 pounds gamma of benzene hexachloride, 2 pounds actual parathion, and 34.8 pounds chlordan, and significant for 2 pounds gamma of the high gamma type benzene hexachloride. There was no significance according to analyses of the cucumber stands at completion of harvest.

Analyses of variance of stand counts were computed and significant differences were found between stands of the different treatments for bush beans, beets, cauliflower, Swiss chard, and turnips; whereas, no significance was found for pole beans, carrots, cucumbers, onions, and squash. Bush beans and turnips showed a highly significant lower stand count in treatments of 2 pounds gamma benzene hexachloride, 2 pounds actual parathion, and 34.8 pounds actual chlordan, as compared to the untreated check. Stand counts of beets and Swiss chard, when compared with the untreated check, were highly significantly less in the 2 pounds gamma benzene hexachloride treatment. Stands of cauliflower and Swiss chard were highly significantly lower in the 2 pounds actual parathion treatment. No significant differences were found for any vegetables tested in treatments of 0.5 pound gamma of the high gamma benzene hexachloride and 5 pounds actual chlordan.

Soil surface treatments using beznee hexachloride definitely caused an off-flavor in fresh peas and pole beans, but less definite responses for bush beans, carrots, and cucumbers. Off-flavor in fresh samples of vegetables grown in the high gamma type benzene hexachloride was less noticeable than with benzene hexachloride. Parathion and chlordan seemed to reduce the quality of the fresh peas, pole beans, and bush beans, but was questionable for carrots and cucumbers.

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Effect of Insecticides on the Flavor of Peaches—1948[1]

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Since benzene hexachloride was first used on peaches for the control of plum curculio, there have been numerous rumors and a few reports of it affecting the flavor of peaches. Snapp (1947) reported that benzene hexachloride adversely affected the flavor of fruit when used one month before harvest. Smith reported that during the 1946 season benzene hexachloride caused an off-flavor in fresh peaches when it was used too near harvest. It was suspected that the flavor of the canned products also was adversely affected. In 1947 fruit was canned from trees which had received five applications of benzene hexachloride, the last application one week before harvest, and it was noted that peaches from these trees were distinctly off-flavor (Smith 1948). Davis (1948) reported that "benzene hexachloride in water can be detected by smell in one part per ten million, and by taste in one part per million." Davis also stated that "there seemed to be little correlation between early harvested peach varieties or seedlings and amount of residual benzene hexachloride in the canned product detectable by taste or smell."

In order to check on the effect of various insecticides on the flavor of peaches an experiment was set up (1948) at the Peach Research Laboratory at Eagle Springs, North Carolina, using different insecticides[3–8] (Table 1). These studies were conducted on the Elberta variety using plots of 4×4 trees. Wettable sulfur was used at the rate of 6 pounds per 100 gallons of water in all sprays except those labeled Pan-Peach. Sulfur was also applied to all plots July 6 and 16.

Fruit for observation was harvested from the center four trees of each plot. Thus two border rows separated the harvested plots. This arrangement was deemed necessary to avoid contamination from spray drift. The sprays were applied with a power sprayer using 3-nozzle brooms fitted with No. 4 or 5 discs. The trees were sprayed so thoroughly at each spraying that the drip would wet the ground beneath the trees.

Insecticide residue analyses were made on fruit harvested July 15 and 16. The peaches were picked directly into half-bushel baskets, dusted with sulfur and shipped by express to various laboratories for analyses.

Fruit for flavor tests was harvested July 22 and 27 and canned July 26 and August 2. Two to four bushels of fruit were picked from the 4 center trees of each experimental plot at each picking and taken directly to Raleigh. The fruit was held at room temperature (80–90° F.) until ripe enough for eating as fresh fruit or until proper canning maturity had been attained. The July 27 picking was held in cool storage July 31 and August 1. One to four pecks of the best fruit were then selected from each of the lots and either canned or used in the fresh fruit taste tests.

Taste tests were made first on fruit receiving the maximum number of sprays. If no off-flavor was detected in this fruit it was not deemed necessary to check on the fruit receiving fewer sprays.

EXPERIMENTAL PROCEDURE FOR FRESH FRUIT TASTE TESTS.—It was assumed that one person cannot effectively taste more than 5 samples at one time, so each experiment was set up to test 5 treatments. Each treatment was tasted by 20 different people in each test. The sample submitted to any one taster from a treatment was made up of a small cube from each of 10 different fruits, the material having been peeled and cut immediately before testing. Each person was given a tray with a sample cup from 5 treatments, each identified by code. He was asked to score each sample on a 1 to 5 scale as follows: 1—very good, 2—good, 3—medium, 4—poor, 5—very poor. The order in which the samples were tasted by an individual was specified. In some tests this was determined at random and in others it was controlled so that the effects of order of

[1] Published with the approval of the Director as Paper No. 304 of the Journal Series.

[2] Research Professor of Entomology; Research Professor of Horticulture and Plant Science Statistician, respectively.

[3] Chlordan (50% wettable powder) Julius Hyman & Company.

[4] Toxaphene (25% wettable powder) Hercules Powder Company.

[5] Parathion (25% wettable powder) American Cyanamid Company.

[6] *Pan-Peach*—A proprietary product containing acid lead arsenate, sulfur and safeners—Taylor Chemical Company.

[7] Benzene hexachloride (10% gamma isomer) California Spray Chemical Corp.

[8] Sulfur—Taylor Chemical Company.

tasting could be measured. No selection of tasters was exercised and no training was given them. They represented professional staff, secretaries, laboratory technicians and casual visitors.

The combinations of treatments which were tested together are indicated in table 2.

EXPERIMENTAL PROCEDURE FOR CANNED FRUIT TASTE TESTS.—The fruit for canning was dipped in boiling water for 40 seconds and peeled. The peaches were then halved, pitted, and each half was subdivided into six segments by a mechanical slicer. Each of the six segments was put in a different No. 2 Sanitary can. Thus six cans were filled at a time, approximately 20 peaches being required. The weight of each can was adjusted to 470 grams. The cans were completely filled with a medium or 40 per cent syrup, exhausted in a steam tunnel to an internal temperature of 140° F., sealed and processed in boiling water for 15 minutes.

The first four tests on canned fruit (VIII–XI) were conducted in the Food Processing Laboratory at the North Carolina Experiment Station and 20 people per treatment were used. It was decided to find whether reducing the number of samples that one person was asked to evaluate would affect the experimental accuracy. Therefore, in tests IX, X, and XI only 3 samples were given to each taster instead of 5. Test XII was offered to shoppers in a local food market. In this test only three samples were given to any taster although 5 treatments were included in the test. A balanced incomplete block design was used on a total of 100 tasters. This gave 60 tasters per treatment. Test XIII was prepared and taken to people in their offices and covered 39 tasters, 20 with one set of cans and 19 with a second set. Each person tasted 5 treatments.

RESULTS OF TASTE TESTS ON FRESH FRUIT.—Tests I and IV (Table 2) compared various times of applying benzene hexachloride. The greatest number of applications of benzene hexachloride (4A) gave the highest scores indicating poorest flavor. The two late applications of benzene hexachloride (8A) ranked next (see mean of tests I and IV) although not significantly poorer than the other two benzene hexachloride treatments (6A and 7A). Tests II and V made similar comparisons except that one late application of benzene hexachloride (8C) was substituted for the 6 applications (4A). In this test the two late applications of benzene hexachloride (8A) gave the poorest flavor (highest score) followed closely by one late application of benzene hexachloride (8C). In tests I, II, IV and V the two early (7A)

Table 1.—Dates of application, materials, and amounts of each material used in the experiment testing the effect of insecticides on the flavor of peaches.

Plot No.	Spray Materials	Dates Sprayed Pounds per 100 Gallons					
		3/26	4/2	4/15	4/23	6/15	7/13
1A	Chlordan 50%	2	2	2	2	2	2
1B	Chordan 50%	2	2	2	2	2	—
2A	Toxaphene 25%	4	4	4	4	4	4
2B	Toxaphene 25%	4	4	4	4	4	—
3A	Parathion 25%	1	1	1	1	1	—
3B	Parathion 25%	1	1	1	1	—	—
	Lead Arsenate	—	—	—	—	16	—
4A	Benzene hexachloride[1]	2	2	2	2	2	2
5A	Benzene hexachloride[1]	2	2	2	2	2	—
6A	Benzene hexachloride[1]	2	2	2	2	—	—
	Lead Arsenate	—	—	—	—	16	—
7A	Benzene hexachloride[1]	2	2	—	—	—	—
	Lead Arsenate	—	—	16	16	16	—
8A	Benzene hexachloride[1]	—	—	—	—	2	2
	Lead Arsenate	16	16	16	16	—	—
8B	Parathion 25%	—	—	—	—	—	1
	Lead Arsenate	16	16	16	16	16	—
8C	Benzene hexachloride[1]	—	—	—	—	—	2
	Lead Arsenate	16	16	16	16	16	—
9A	Lead Arsenate	16	16	16	16	16	—

[1] Benzene hexachloride, a wettable powder containing 10% gamma isomer. Sulfur, 6 pounds per 100 gallons, used in all sprays except lead arsenates which is a proprietary material consisting of acid lead arsenate, sulfur and safeners.

Table 2.—Results of taste tests on fresh fruit.

Plot No.	Treatment	Average Scores Fruit Picked 7/22	7/27	Mean of Both Dates
		Test I	*Test IV*	
4A	6 Benzene hexachloride[7]	3.00	3.40	3.20
7A	2 Benzene hexachloride Early	2.75	2.50	2.62
6A	4 Benzene hexachloride Early	2.20	2.85	2.52
8A	2 Benzene hexachloride Late	2.70	2.85	2.78
9A	5 Lead arsenate[6]	2.15	1.65	1.90
L.S.D.* (.05)		.67	.63	.46
		Test II	*Test V*	
6A	4 Benzene hexachloride Early	2.45	2.50	2.48
7A	2 Benzene hexachloride Early	2.55	2.35	2.45
8A	2 Benzene hexachloride Late	3.60	3.65	3.62
8C	1 Benzene hexachloride Late	3.05	3.30	3.18
9A	5 Lead arsenate[6]	1.95	2.00	1.98
L.S.D. (.05)		.66	.63	.46
		Test III	*Test VI*	
1A	6 Chordan	1.65	2.45	2.05
2A	6 Toxaphene	2.20	2.10	2.15
3A	5 Parathion	2.40	1.75	2.08
6A	4 Benzene hexachloride Early	3.10	2.90	3.00
9A	5 Lead arsenate[6]	2.20	1.90	2.05
L.S.D. (.05)		.53	.52	.36
			Test VII	
1A	6 Chlordan		2.80	
3A	5 Parathion		2.10	
6A	4 Benzene hexachloride Early		2.10	
8B	1 Parathion Late		2.20	
9A	5 Lead arsenate[6]		1.60	
L.S.D. (.05)			.52	

and 4 early (6A) applications of benzene hexachloride gave a slightly poorer flavor than the lead check (9A). The difference was not great enough to be significant in three of the tests but the cumulated evidence indicates that these treatments undoubtedly convey a slight flavor to the fruit.

Tests III and VI compared the flavor imparted by the 5 different insecticides used in the experiment. There was some variation in the performance of these treatments on the 2 picking dates but the averages indicate that only the 4 applications of benzene hexachloride (6A) affected flavor. Test VII compares somewhat the same treatments except that one late application of parathion (8B) was

Table 3.—Results of taste tests on canned fruit.

Plot No.	Treatment	Average Scores of Test VIII	IX	X	XI	XII	XIII
1A	6 Chlordan	1.70	—	—	2.65	2.15	—
2A	6 Toxaphene	2.15	—	—	—	—	—
3A	5 Parathion	2.55	1.76	—	2.30	1.87	—
4A	6 Benzene hexachloride	—	—	4.04[1]	—	—	—
6A	4 Benzene hexachloride Early	2.65	2.65	3.29[1]	—	2.51[1]	2.51
7A	2 Benzene hexachloride Early	—	—	—	—	2.23	2.15
8A	2 Benzene hexachloride Late	—	—	—	—	—	4.05[1]
8C	1 Benzene hexachloride Late	—	—	—	—	—	3.54[1]
9A	5 Lead arsenate	2.55	2.70	2.56	2.30	2.10	2.62
L.S.D. (.05)		.47	.45	.49	.57	.33	.41
No. Tasters/Treat.		20	20	20	20	60	39

[1] Significantly poorer than the lead check.

Table 4.—Comparison of the effects of lead, parathion, chlordane and 4 early applications of benzene hexachloride on fresh and canned fruit flavor.

(Averages from individual tests)

	TEST	LEAD	PARATHION	4 BENZENE HEXACHLORIDE	CHLORDAN
Fresh Fruit	III	2.20	2.40	3.10	1.65
	VI	1.90	1.75	2.90	2.45
	VII	1.60	2.10	2.10	2.80
Average		1.80	2.08	2.70	2.30
Canned Fruit	VIII	2.55	2.55	2.65	1.70
	IX	2.70	1.76	2.65	2.13[1]
	XI	2.30	2.30	2.85[1]	2.65
	XII	2.10	1.87	2.51	2.15
Average		2.41	2.12	2.44	2.16
Average (all tests)		2.19	2.10	2.68	2.22

[1] Supplied as "missing values."

substituted for chlorinated camphene. For some unexplainable reason chlordan gave a significantly poorer score than the other treatments in test VII. There was a suggestion of the same response in test VI on this particular lot of fruit (second harvest).

These 7 tests may be summarized as follows: Applications of benzene hexachloride late in the growing season impart a definite flavor to the fresh ripe fruit. Two or four early applications of benzene hexachloride also affect fruit flavor but the effect is not as marked nor as objectionable as the later applications. Parathion and chlorinated camphene treatments gave no indications of adverse effects on fruit flavor. The results on chlordan are conflicting, in one picking it was significantly better than lead and in the second it was significantly poorer than lead.

RESULTS OF TASTE TESTS ON CANNED FRUIT.—The results of the 6 canned fruit tests are given in Table 3. Parathion is consistently as good or better than the lead check. Chlorinated camphene and chlordan were also as good as the lead check.

Tests XII and XIII gave no indications of adverse effects of 2 early applications of benzene hexachloride. However, the other applications of benzene hexachloride (4A, 8A, 8C) affected the canned fruit as they did the fresh in that they gave it a definite, objectionable flavor. The effects of 4 early applications of benzene hexachloride (6A) was not as pronounced in the canned as in the fresh fruit in some of the individual tests.

Table 4 brings together the information on chlordan, parathion and 4 applications, of benzene hexachloride in comparison with the lead check in tests where they occur together. An analysis of variance of this table indicates that there are no greater differences between the treatment effects on fresh and canned fruit than would be expected by chance. That is, the variation in reaction of the treatments from one test to another is as great as the interaction of treatments with canned and fresh fruits. However, the over-all average difference between 4 applications of benzene hexachloride and the other treatments is significant. The effect of chlordan here compares very favorably with the lead check.

SPRAY RESIDUE ANALYSES.—Samples of peaches from the plots sprayed with benzene hexachloride were submitted to Dr. L. B. Norton, Insecticidal Chemist at Cornell University who supplied the following information:

Table 5.—Residue analyses on fresh fruit from the check plot (9a) and from plots sprayed with benzene hexachloride.

SAMPLE		SURFACE BENZENE HEXACHLORIDE	PULP BENZENE HEXACHLORIDE
4A	6 Benzene hexachloride	2.89 p.p.m.	0.66 p.p.m.
5A	5 Benzene hexachloride	0.76	0.19
6A	4 Benzene hexachloride	0.29	0.04
7A	2 Benzene hexachloride Early	0.03	0.01
8A	2 Benzene hexachloride Late	2.95	
8C	1 Benzene hexachloride Late	1.87	0.57
9A	5 Lead arsenate	0.03	0.06

"The surface residue figures were obtained by stripping the residue with benzene. For the pulp

analyses, the stripped samples were dipped in hot water, peeled, pulped and the benzene hexachloride separated by a steam distillation method on which we hope to report later. Final analysis was made in each case by a total chloride method, which would give only the total of all isomers. It is quite possible that the figures in the pulp are too high due to some of the surface material being carried into the pulp by the benzene before peeling."

Samples of peaches from the plots sprayed with parathion were submitted to the American Cyanamid Company for residue analyses and the method described by Averell & Norris (1948) was used. The following data was supplied by Dr. P. R. Averell: "Figures under 0.1 p.p.m. should not be ascribed too great reliability as absolute values, as the precision is low for such small amounts. It is evident, from sample 8B, however, that the residue is practically all on the surface."

Table 6.—Residue analyses on fresh fruit from plots treated with parathion and the check plot.

Sample Number		PPM. Parathion Total Weight Basis		
		Surface	Peel	Pulp
3A	5 Parathion	0.01	0.01	0.02
3B	4 Parathion	0.00	0.01	0.01
8B	1 Parathion Late	0.38	0.31	0.01
9A	5 Lead arsenate	0.00	0.03	0.02

Samples of canned peaches from plots (3A, 3B, and 8B) sprayed with parathion were also analyzed for parathion by Dr. Averell but "none was found in any of the samples."

Samples of peaches from the plots sprayed with chlorinated camphene were submitted to the Hercules Powder Company for residue analysis. The following data was supplied by Dr. Floyd Diephuis and Dr. Charles L. Dunn:

"The samples were analyzed for chlorinated camphene (Table 7) using essentially the method described by Wichman *et al.* (1946) for the determination of DDT on apples and pears."

Table 7.—Residue analyses of fresh fruit for plots treated with chlorinated camphene and the check plot.

Sample		P.P.M. Organic Chloride	Av. P.P.M. Organic Chloride[1]	Control 9A
2A	6 Chlorinated camphene	3.8, 4.3	4.1	5.7 p.p.m.
2B	5 Chlorinated camphene	2.5, 3.6	3.1	4.3
9A	5 Lead arsenate	0.2	0.2	0

[1] Calculated as chlorinated camphene corrected for control 9A.

A residue tolerance has not been established for any of the organic insecticides discussed in this paper. However, the residue analyses are given so that they might serve as an indication for future workers.

It is of interest to note that parathion was found in measurable amounts only on fruit from the plot (8B) which was sprayed July 13 and picked July 16. The residue analyses were made within two weeks of the time the peaches were sprayed.

In the case of benzene hexachloride it appears there is a correlation between the amount of residue in or on the peach and the intensity of the off-flavor.

DISCUSSION.—It is apparent from tables 2 and 3 that there was considerable variation in the relative effects of the treatments from one taste test to another. For example, 4 early applications of benzene hexachloride was almost the same as the lead check in test I, but in test IV it was very much poorer. The chlordan treatment in experiment III gives a similar kind of variation. It is not clear from these studies why such differences occur. Whatever the cause of the test-to-test variations, it is logical to assume that the average of several tests more nearly represents the true values of the effects from any given treatment.

The errors used in testing treatment differences in this experiment did not include plot-to-plot variations since only one field replication of each treatment was available.

In the canned fruit there were no measurable differences from one can to another on the same treatment. There was no reduction in errors of scoring by cutting the samples per person from 5 to 3. As long as each sample is evaluated on its own merit and not necessarily related to the other, one person can effectively taste 5 samples at one sitting.

There were no indications of effects of order of tasting the treatments. It was suspected that once a person had the flavor of benzene hexachloride in his mouth he could no longer discriminate. This did not prove to be the case in the experiments where order of tasting was controlled. However, there was a regular increase in the error in experiments which included samples with marked benzene hexachloride flavor. The above contention cannot be ruled out categorically, but another explanation seems more likely.

Some people definitely liked the benzene hexachloride flavor because it seemed to give the fruit a more bland flavor. Such tasters tend to score the samples in reverse order to those who do not like the benzene hexachloride flavor. Since the error measured is the taster × treatment interaction, a few people in each test would inflate the interaction.

This poses the question of who should be used for tasters and whether they should be trained. The answer to this question depends on the basic information required. If the information desired is whether the consuming public will discriminate against fruit treated with these insecticides, the unselected and untrained tasters will give such information. If, on the other hand, it is desired to know whether the fruit possesses a specific flavor the information may be had more specifically and more accurately by using tasters selected for their powers of discrimination and instructing them as to the specific flavor being sought. The primary objective of the above tests was to determine whether or not the consuming public would discriminate against fruit sprayed with certain of the organic insecticides which have shown promise in controlling the plum curculio.

SUMMARY.—Peach trees were sprayed with benzene hexachloride (10 per cent gamma isomer), chlordan, chlorinated camphene, parathion, or lead arsenate at different times during the growing season. Samples from the various plots were picked when the peaches were ripe, analyzed for spray residue and taste-tested for off-flavor. In the flavor tests the peaches receiving only lead arsenate were used as a standard. Flavor tests were conducted on fresh and canned fruit.

Analyses of residue on the fruit at harvest were made for benzene hexachloride, parathion and chlorinated camphene.

In the flavor tests, benzene hexachloride affected the flavor of fresh fruit. The flavor of the canned fruit was similarly affected by the benzene hexachloride except where it was used only in the petal-fall and shuck-off sprays. The off-flavor became more noticeable as the number of sprays were increased or as they were applied nearer harvest.

There was some variation in the effects of parathion and chlordan in the flavor tests. Twice fruit from the parathion plot was significantly better than any other fruit in the test, while in one test it was poorer than fruit from the lead plot. Fruit from the chlordan plot was by far the best in two tests. In another test it was even significantly worse than fruit which had received 4 applications of benzene hexachloride. However, when results of all the tests were pooled there was no significant difference between the effects of lead arsenate, chlordan or parathion on the flavor of the fruit.

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Oils in Dormant Sprays to Control European Fruit Lecanium and Terrapin Scale on Peach[1]

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Spraying with dormant oils has been the standard treatment to control terrapin scale, *Lecanium nigrofasciatum* Perg. and the European red mite, *Paratetranychus pilosus* (C. & F.), in peach orchards in Pennsylvania for several years. A report by Steiner (1942) on the efficiency of a certain oil of low paraffinacity as a dormant spray for controlling these pests served as the basis for recommendations to growers. Extensive use of dormant oils of this type by commercial peach growers has verified Steiner's findings which are interpreted as follows: the concentration of a low paraffinic-type oil that is optimum insecticidally is at the threshold of phytotoxicity.

During 1948, the European fruit lecanium, *Lecanium corni* Bouché, became an important pest of peach in south central Pennsylvania. Although Wheeler *et. al.* (1948) reported satisfactory control of this insect with high paraffinic oils at 2 per cent concentration, no report is available on the efficiency of high paraffinic-type oils as killing agents for terrapin scale. Since Pearce *et al.* (1942) and Chapman *et al.* (1944) reported that high paraffinic-type oils are more efficient as killing agents than low paraffinic-type oils, the tests reported here were designed to compare some commercial oil products of both types as toxicants for controlling European fruit lecanium and terrapin scale and to check their influence on the set of peach fruits when applied at different times during the dormant and delayed dormant periods.

The composition of each oil product tested is listed in table 1. Other insecticides included in the tests are listed under the heading "Materials in 100 Gal." in table 2. All the treatments under this heading in tables 2 and 3 were applied to old Elberta peach trees on the Roy Heckenluber farm in Arendtsville. With the exception of the treatments in table 3, all sprays were applied at 450 p.s.i. with the gun open only as much as necessary to effect coverage of the trees. A disc with a No. 10 orifice was used in all cases.

Mortality counts of both scale insects were made in the laboratory. It was impractical to take mortality data before the delayed dormant period because the insects did not respond normally to the transfer from the orchard to the laboratory until then. Infested twigs were cut from the test trees and placed in jars of water on a bench in the laboratory. Within a few days, living European fruit lecanium on the twigs began to grow and the living and dead specimens were counted. The results are listed in table 2 as "E.F.L. Per Cent Dead."

Living terrapin scales responded to the same water treatment by secreting honeydew. The bodies of dead terrapin scales became shriveled and discolored. In table 2, where the listing under the heading "Terrapin Per Cent Dead" reads "Low," the terrapin scales on the twigs from the respective treatments secreted honeydew so copiously it showered down onto the bench top. Trial counts of the scales on some of these twigs showed that less than 50 per cent of them were dead. Results of all treatments are tabulated in tables 2 and 3.

To check the set of fruits on the trees, six twigs were tagged on each tree and the number of fruit buds on each twig recorded. A week after petal fall, the peaches on the tagged twigs were counted. In tables 2 and 3 the figures are presented as per cent of fruit set.

Table 1.—Composition of oil products.

OIL LETTER	I[3]	M[4]	N[5]	O[6]	P[7]	Q[8]
Gravity[1] °API	34	34.7	34.7	29	31.8	28.8
Viscosity Index (ASTM)	117				100	
Unsulfonated Residue[2] (ASTM)	92	96	96	80	90	88
Pour Point	25					30
Viscosity (Saybolt 100′ F.)	100–105	90	90	85	119	114
Per Cent Oil	97	83	96	83	99	83

[1] 31 min. for high paraffinic-type oil.
[2] 90 min. indicates phytonomic oils.
[3] *I. S. Oil*, Eastern States Farmers' Exchange.
[4] *Orthol D Emulsion*, California Spray-Chemical Corp.
[5] *Orthol D Soluble*, California Spray-Chemical Corp.
[6] *Kleenup*, California Spray-Chemical Corp.
[7] *Shell Neutral Superior Spray Oil*, Shell Oil Co.
[8] *HyTox Oil "83,"* Miller Chemical Co.

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[2] Acknowledgement is made of the valued assistance of Harvey W. Dickert and Guy A. Herring.

Table 2.

MATERIALS IN 100 GAL.		DATE APPLIED	CONDITION OF TREES	E.F.L. DEAD	TERRAPIN PER CENT DEAD	FRUIT SET
		1948				
Oil M 50% Mixture of aliphatic thiocyanates[1]	1 gal. 1 pint	11/15	Dormant	100%	Low	82%
Oil M Lime Sulfur[2]	1 gal. 5 gal.	11/15	Dormant	86	Low	—
Oil O Lime Sulfur	1 gal. 5 gal.	11/15	Dormant	99	Low	—
Oil M	3 gal.	11/15	Dormant	100	Low	82
Oil O	4 gal.	11/15	Dormant	100	Low	88
		1949				
Oil Q 19% Sodium salt of dinitro-orthocresol[3]	1 gal. 1 qt.	2/24	Early D. Dormant	100	Low	70
Oil L 19% Sodium salt of dintiro-orthocresol	1 gal. 1 qt.	2/24	Early D. Dormant	98	Low	79
19% Sodium salt of dinitro-orthocresol	1 qt.	3/14	Medium D. Dormant	92	Low	79
Oil P 19% Sodium salt of dinitro-orthocresol	1 gal. 1 qt.	3/14	Medium D. Dormant	100	Low	53
36% Dinitro-sec-butylphenol, tri-ethanolamine salt[4]	1 qt.	3/14	Medium D. Dormant	98	Low	53
Oil P	2 gal.	3/14	Medium D. Dormant	100	71	85
Oil P 25% Parathion[5]	1 gal. 1 lb.	3/14	Medium D. Dormant	98	Low	74
Oil Q	4 gal.	3/14	Medium D. Dormant	100	84	78
Check (No treatment)				30	12	83

[1] *Lethane Special*, Rohm and Haas Co.
[2] Mfg. by Adams County Fruit Packing and Distributing Co.
[3] *Elgetol*, Standard Agricultural Chemicals, Inc.
[4] *DN-289*, Dow Chemical Co.
[5] *Thiophos*, American Cyanamid Co.

Most of the essential information regarding the tests may be learned from the tables. Points not covered are: (1) Many of the fruits that set on the oil-parathion treated trees (Table 2) were shriveled and weak at the time the count was made. (2) On the second, third and fifth nights following the application of treatments in table 3, there were heavy frosts. (3) All the materials in table 3 were applied at 450 p.s.i. through a disc with a No. 10 orifice. Treatments 1D, 2D and 3D were applied as mists. Treatments 1E, 2E and 3E were applied with the gun wide open. Differences in the percentages of dead

Table 3.[1]

TREATMENT NUMBER	MATERIALS IN 100 GALLONS	TYPE OF APPLICATION	TERRAPIN PER CENT DEAD	FRUIT SET
1D	Oil L 3 gal.	Mist	85%	83%
1E	Oil L 3 gal.	Gunned	100	85
2D	Oil N 3 gal.	Mist	90	84
2E	Oil N 3 gal.	Gunned	97	91
3D	Oil Q 4 gal.	Mist	73	27
3E	Oil Q 4 gal.	Gunned	99	50
4D & 4E	Check (no treatment)		24	93

[1] Applications were made on March 30, 1949 when 18 per cent of the blossoms were open.

terrapin scales and in the set of fruit may be noted under the appropriate headings.

CONCLUSIONS.—The data in table 2 show clearly that European fruit lecanium scales are easier to kill with dormant sprays than terrapin scales. They also indicate the inadvisability of spraying during the fall to control terrapin scales in Pennsylvania peach orchards. The limited evidence regarding dinitro-sec-butylphenol, triethanolamine salt, sodium salt of dinitro-ortho-cresol with oil, and parathion-oil is sufficient only to suggest caution in their use on peach trees.

Two conclusions may be drawn from the data in table 3: (1) low paraffinic-type oils as represented by the oil in treatments 3D and 3E are not so safe as high paraffinic-type oils for application to peach trees in the pink bud stage of development; (2) oil applied as a driving spray will kill a higher percentage of terrapin scales than the same oil applied as a mist.

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Cyclocephala borealis as a Turf Pest Associated with the Japanese Beetle in New York[1]

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One of the objects of research on the Japanese beetle, *Popillia japonica* Newman, in New York, has been the evaluation of the biological control measures which have been developed by the United States Department of Agriculture and widely used within the state. Since the parasitic organisms so introduced are expected to give a readily measurable degree of control only after they have had several years to multiply on the host populations, the evaluations should normally begin where the organisms were first released, which, in New York, is the area within about 25 miles of New York City. Recent field investigations in that area were complicated by the presence of at least three scarabaeoid species which occurred with the Japanese beetle in mixed populations. Two of these, the oriental beetle, *Anomala orientalis* Waterhouse, and the Asiatic garden beetle, *Autoserica castanea*, Arrow, have been dealt with in a contemporary paper (Adams 1949). This is a preliminary report on the species ranked fourth in importance, *Cyclocephala borealis* Arrow.[2]

The limits of distribution of *Cyclocephala borealis* in New York are not yet known. One difficulty is that although *C. borealis* is probably the only representative of the genus occurring as a pest in the state, the determination of the species is not feasible from larval specimens but requires the male adult (Ritcher 1944). No survey of the adults, which fly at night, has been attempted. The author has seen adult specimens taken around New York City in various years running back to 1902. Occasional adults taken in Westchester and Nassau Counties in this study and a series reared from larvae dug near the turf plots in Nassau County, described below, were all *C. borealis*. The author has found larvae, presumed to be *C. borealis*, in western Suffolk and southern Rockland Counties. White (1947) found *Cyclocephala* larvae in Putnam County about 35 miles north of New York City. North of this point around Pough-

[1] Annual Meeting, 1948. Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 793, 1949.

[2] The larvae of *Cyclocephala* (*Ochrosidia*) species are sometimes called "annual white grubs." This term serves to distinguish them from the larvae of *Phyllophaga* species, but not from the larvae of *Anomala*, *Autoserica*, *Popillia* or *Serica* species with which they occur in New York. A distinctive common name based upon the adult seems desirable. The dark band about the eyes of various *Cyclocephala* species suggests the term masked chafer. It has been proposed to the Association that *C. borealis* be termed the northern masked chafer.

keepsie, in Dutchess County, the author has made hundreds of square-foot diggings in turf each year in the period 1943 through 1948 without finding any trace of *Cyclocephala*. The distribution of *C. borealis* in Westchester County just north of New York City is probably continuous with that in the adjoining county of Fairfield in Connecticut, reported by Johnson (1941).

IMPORTANCE.—In the fall of 1943 and the spring of 1944 on each of 20 golf courses around New York City, in Nassau and Westchester Counties, 10 to 30 or more square-foot diggings were made in a survey of the Japanese beetle. Only a few *Cyclocephala* forms were found. In 1947 and 1948 *Cyclocephala* larvae were readily found at some of these courses and on two of them there were several areas of injured turf in which the *Cyclocephala* larvae were evidently predominant in the scarabaeoid population. These areas were mostly of less than 1 acre in extent and occurred mainly on unwatered roughs. The observed damage would have been of little importance had it not been a source of misunderstanding. Property owners, unaware of the mixed nature of the grub populations regarded the fresh injury as a sign of resurgence of the Japanese beetle. Where the areas had been previously treated with milky disease spore powder or had received a liberation of Japanese beetle parasites, the turf injury was regarded as a sign of failure of these agents of control.

CHEMICAL CONTROL.—In the fall of 1947 it was apparent that certain sod areas containing destructive numbers of *Cyclocephala* larvae would be treated in 1948 as though infested by the Japanese beetle alone. Although DDT at 25 pounds to the acre had proved effective for the control of larvae of the Japanese beetle and the Asiatic garden beetle, there was no assurance that it would control *Cyclocephala*. According to unpublished reports DDT had not controlled certain unidentified larger "white grubs," a term which, in New York, usually suggests *Phyllophaga* species, but in other states might refer also to *Cotinus nitida* L. or *Cyclocephala* species (Noer 1948). There was a similar question regarding chlordan which, following the discovery of its toxicity to Japanese beetle grubs by Fleming (1947), was coming into commercial use for turf treatment.

For a preliminary test of the newer materials six plots of 1000 square feet each were laid out on a mowed rough at the Plandom Golf Course near Port Washington on Long Island. The soil was a well-drained sandy loam. The mixtures applied are shown in table 1. Application was made with a fertilizer spreader on May 6,

Table 1.—Insecticidal mixtures applied on turf plots of 1000 square feet each at the Plandom Golf Course, Plandom, Long Island, N. Y., May 6, 1948.

Plot	Pounds Applied			Rate of Toxicant to the Acre	
	DDT 10%[1]	Chlordan 5%[2]	Talc[3]	DDT	Chlordan
A	6.0	—	6.0	26.1	—
B	12.0	—	—	52.2	—
C	—	5.0	7.0	—	10.8
D	—	10.0	—	—	21.7
E	3.0	2.5	6.5	13.0	5.4
F	6.0	5.0	—	26.1	10.8

[1] DDT supplied as 10 per cent powder by Plant Products Corp., Blue Point, N. Y.
[2] Chlordan supplied as *Synklor-5-D*, Naugatuck Chemical Co., Naugatuck, Conn.
[3] Talc supplied as EMTCO-23 by Eastern Magnesia and Talc Co., Burlington, Vt. Added to secure more uniform distribution.

1948. Rain fell on May 7. Results obtained in the spring were undecisive owing to the meager grub population. The average grub population in the 14 square feet dug in and around the plots on May 6 was *Cyclocephala* 4, *Popillia* 3.6 and *Autoserica* 12.6. Diggings made June 21 merely indicated that control in the spring was far from complete on most of the plots. In the fall, Sept. 20 to October 19, a total of 24 square-foot diggings were made in the untreated check area just outside the plots. The average square-foot population was as follows: *Cyclocephala* 12.2, *Popillia* 11.5, and *Autoserica* 10.5. Within each treated plot 10 square-foot samples were taken; the new generations of all three species were found to be virtually eliminated in all the plots.

MILKY DISEASE.—White (1947) has listed instances of milky disease in field-dug *Cyclocephala* larvae including two cases from New York. One additional instance is reported here. In the fall of 1947 Mr. J. R. Tank, of the State Department of Agriculture and Markets sent the author some *Cyclocephala* larvae which he had dug at Dyker Beach Golf Course in

Brooklyn, including one he recognized as affected by the disease. The specimen was examined by Dr. S. R. Dutky of the Japanese Beetle Laboratory at Moorestown, N. J. who identified the infecting organism as a *Cyclocephala* strain of *Bacillus popilliae* Dutky. That this strain is not identical with that occurring in *Popillia* larvae is indicated by observations at the Plandom Golf Course. The insecticide plots at that course, described above, were deliberately laid out on one of the 7 half-acre areas where, in April, 1941, standard milky disease spore powder had been applied on a high population of *P. japonica*. In a visit to the course in 1943 the author found the disease established in that species. In 1948, 12.5 per cent of the *Popillia* larvae dug in the fall showed milky disease; but no disease was observed in the larvae of *Cyclocephala* and *Autoserica* dug in the same area.

TIPHIA PARASITE.—Parasitism of *Cyclocephala* larvae at Moorestown, N. J. with a *Tiphia* species was reported by Jaynes & Gardner (1924). Similar parasitism was observed at the Plandom Golf Course in the fall of 1948. As adult parasite taken on September 21, was identified by Dr. H. W. Allen of the Oriental Fruit Moth Laboratory at Moorestown, N. J. as *Tiphia relativa* Vier. On September 21, hatched parasite larvae were present on some of the grubs, being attached at their characteristic position on the dorsal side of the thorax of third instars. On October 19, of 200 larvae dug, 20 bore parasite larvae of various sizes, and 17 others bore blackened scars at the point where the parasite is normally attached. Some freshly formed cocoons were also found. No parasitism by this species was observed on *Popillia* or *Autoserica*.

SUMMARY.—Grub damage to turf in the vicinity of New York City in 1947 and 1948 was found to be due to mixed populations of scarabaeoid larvae. In some cases the larvae found to be predominant were of the genus *Cyclocephala*, presumably all *C. borealis* Arrow. (A common name, northern masked chafer, is proposed for that species.) *Cyclocephala* larvae in New York seemed to occur only in the area within 35 miles of New York City. The turf damage to which these insects contributed was popularly mistaken for a resurgence of the Japanese beetle. This in turn, threatened to reduce public confidence in the program for biological control of that species. In preliminary field tests DDT, at the rates of about 26 and 52 pounds to the acre, chlordan at 10.8 and 21.7 pounds to the acre and mixtures of DDT and chlordan, applied May 6, were completely effective against the new generation in the fall. Although milky disease was found in one-eighth of the Japanese beetle larvae dug near these plots in the fall it was not found in the *Cyclocephala* larvae inhabiting the same soil. Larvae of *Tiphia relativa* Vier were found attached to about one-tenth of the *Cyclocephala* larvae dug near these plots in mid-October.

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Laboratory Evaluation of Larvicides for Red-Banded Leaf Roller and Notes on Injury to Grapes[1]

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The sudden increase of the red-banded leaf roller, *Argyrotaenia velutinana* Walker, in northeastern United States, particularly in apple orchards, has been widely noted. It was also found more commonly in vineyards during 1948 and the possibility of it becoming a pest on grapes has been of concern to the writer, since he is engaged in studies of insect problems of this fruit in the Chautauqua grape belt of New York. An opportunity was afforded to make some laboratory evaluations of various insecticides against the larvae of red-banded leaf roller on grape foliage. A report of this study is given here with some observations on the occurrence of the pest in vineyards. The materials included were DDT,[2] dichlorodiphenyl dichloroethane,[3] methoxychlor,[4] ditolyltrichloroethane,[5] parathion,[6] and lead arsenate.[7] Techniques were developed for obtaining a large number of egg masses and for testing the insecticides against larvae under laboratory conditions. The rearing material was collected in an apple orchard in Niagara County.

METHODS.—A review of the literature gave a reference to the moths depositing eggs on lantern globes (Hough 1926). This procedure, as well as the one using the foliage of plants, seemed unsatisfactory for laboratory studies requiring large numbers of eggs.

Sheets of cellophane and waxpaper with one-half-inch plaits were substituted for bark and leaves on which the moths normally oviposit. A greater number of eggs were deposited on cellophane than on waxpaper. The egg masses as laid on cellophane are shown in figure 1. The oviposition cage used in the tests has a series of "false shelves" of No. 9 wire which support the sheets of cellophane. Two sides of the cage are covered with cloth, one of which serves as an entrance. The wooden sides and ends are covered on the inner side with cloth to prevent moths ovipositing on the wood. The egg masses were cut from the cellophane sheet to facilitate handling, placed in half-pint, wide-mouth glass jars, and incubated at a constant temperature of 72° F. At this temperature hatching began in approximately 5.5 days. Lids were placed tightly on the jars when the eggs reached the "black head" stage of development.

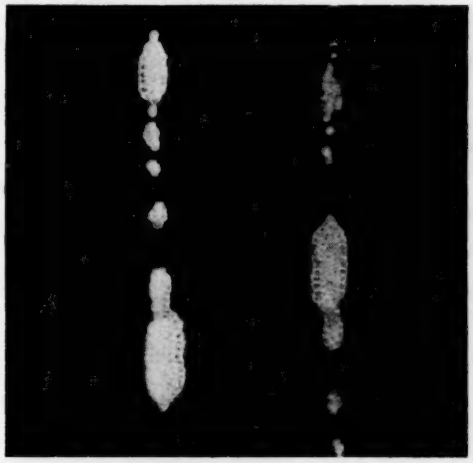

FIG. 1.—Egg masses of red-banded leaf roller on cellophane.

The grape leaves used in this study were of the Beta variety which is characterized by having relatively little pubescence on the lower surface. Leaves near the ends of the shoots were selected and of sufficient size to provide the cutting out of a 2.125 inch disc. These discs were taken near the apex of the leaf to avoid the coarse veining at the base.

Before spraying, each leaf was pinned to a piece of heavy cardboard 5 inches square with the underside up. This was the only side treated. Each mounted leaf was exposed to the spray stream for a uniform period on a turntable. A paint spray nozzle[8] was employed and a liquid pressure of 20 pounds and an air pressure of 60 pounds were maintained. Discs were cut after the spray had dried. Larvae were

[1] Journal Paper No. 797, New York State Agricultural Experiment Station, Geneva, N. Y., April 11, 1949.
[2] DDT, 50 per cent wettable powder. E. I. du Pont de Nemours Co.
[3] DDD, 5 per cent wettable powder. Rohm and Haas.
[4] Methoxychlor, 50 per cent wettable powder. E. I. du Pont de Nemours Co.
[5] Ditolyltrichloroethane, 50 per cent wettable powder. Geigy Co.
[6] Parathion, 25 per cent wettable powder. American Cyanamid Company.
[7] Lead arsenate, acid lead arsenate.
[8] *DeVilbiss WDA.*

Table 1.—Results of tests using various concentrations of dichlorodiphenyl dichloroethane, DDT, parathion and lead arsenate against newly hatched larvae.

Materials[1] and Rates per 100 Gallons	Number Larvae per Test	Per Cent Alive					Per Cent Control Efficiency	
		36 Hours	48 Hours	60 Hours	84 Hours	6 Days	Count 1	Count 2
			Series 1					
50% Dichlorodiphenyl dichloroethane, 8 oz.	50	14.0			0.0		85.3	100.0
50% DDT, 8 oz.	53	79.3			9.4		16.7	90.1
25% Parathion, 8 oz.	62	0.0			0.0		100.0	100.0
Lead arsenate, 8 oz.	49	77.6			44.9		18.5	52.8
Check	62	95.2			95.2			
			Series 2					
50% Dichlorodiphenyl dichloroethane, 4 oz.	102		1.9				97.8	
50% Dichlorodiphenyl dichloroethane, 8 oz.	75		0.0				100.0	
25% Parathion, 1 oz.	98		1.0				98.9	
25% Parathion, 2 oz.	71		0.0				100.0	
50% DDT, 1 lb.	114			21.1			76.4	
Lead arsenate, 3 lbs.	107			36.5			59.2	
Check	142		89.4	89.4				
			Series 3					
50% DDT,[2] 8 oz.	115			15.7		11.3	82.9	87.3
50% DDT,[2] 1 lb.	115			1.7		1.7	98.1	98.1
50% DDT, 2 lbs.	118			0.0		0.0	100.0	100.0
Lead arsenate,[2] 8 oz.	116			56.9		4.3	37.9	95.2
Lead arsenate,[2] 1 lb.	121			34.7		0.0	62.1	100.0
Lead arsenate, 2 lbs.	84			38.1		0.0	58.4	100.0
Check	131			91.6		89.3		
			Series 4					
50% Dichlorodiphenyl dichloroethane, 2 oz.	125			56.0			40.9	
50% Dichlorodiphenyl dichloroethane, 4 oz.	173			26.6			71.9	
50% Dichlorodiphenyl dichloroethane, 4 oz. + Bordeaux mixture 2-2-100	152			23.0			75.7	
50% Dichlorodiphenyl dichloroethane, 8 oz. + Bordeaux mixture 2-2-100	128			3.9			95.9	
25% Parathion, 2 oz.	179			0.0			100.0	
25% Parathion, 4 oz.	163			0.0			100.0	
Check	135			94.8				

[1] All insecticides are wettable powders.
[2] Sodium lauryl sulfate added at rate of 1 ounce per 100 gallons of spray.

then transferred to the treated side of the disc with a camel's hair brush. The number of larvae used per disc was twelve or more except in those tests where larvae were more than three days old, when only five were used. After completing the transfer, each disc was placed with the treated side down in a covered petri dish. The treated and untreated lots were kept at a temperature of 68° F. and the humidity varied from 63 to 70 per cent.

It should be noted that the conditions prevailing in these tests were essentially normal insofar as the newly hatched larvae are concerned and probably also where the 2- and 3-day-old larvae were involved. The situation in case of 16- and 23-day-old larvae was not comparable with field conditions because these larvae are usually feeding beneath silken webs which may or may not influence insecticidal action.

The occasional larva which migrated to the upper surface of the disc and any found dead beyond the periphery of the disc were discarded when the counts were made. All dead individuals on the disc were removed at the time of taking counts. In the untreated checks the mortality of newly hatched larvae ranged from 4.8 to 10.7 per cent and averaged 7.3 per cent. All calculations of efficiency were made according to Abbott's formula.

DISCUSSION OF RESULTS.—The data in

Table 2.—Effectiveness of DDT and three analogs of DDT on 2- and 3-day-old larvae in 72 hours.

Materials[1] per 100 Gallons	Larvae per Test	Per Cent Alive	Per Cent Control Efficiency
Dichlorodiphenyl dichloroethane 4 oz.	79	17.7	81.5
Dichlorodiphenyl dichloroethane 8 oz.	85	4.7	95.1
DDT, 8 oz.	84	64.3	32.8
DDT, 1 lb.	82	39.0	59.2
Methoxychlor, 8 oz.	86	80.2	16.2
Methoxychlor, 1 lb.	84	55.9	41.6
Ditolyltrichloroethane, 8 oz.	94	76.6	20.0
Ditolyltrichloroethane, 1 lb.	84	61.9	35.3
Check	93	95.7	

[1] All materials are 50 per cent wettable powders. Added sodium lauryl sulfate, 1 oz. per 100 gallons.

Table 3.—Results of a preliminary experiment on 16- and 23-day-old larvae.

Materials[1] per 100 Gallons	Larvae per Test	Alive	Control Efficiency
16-day-old larvae	48 hour count		
50% Dichlorodiphenyl dichloroethane, 8 oz.	28	7.1%	92.6%
Check	25	96.0	
16-day-old larvae	5 day count		
50% DDT, 2 lbs.[2]	25	8.0%	91.7%
Lead arsenate, 4 lbs.[2]	25	20.0	79.2
Check	25	96.0	
23-day-old larvae	48 hour count		
50% Dichlorodiphenyl dichloroethane, 1 lb.	25	4.0%	95.8%
25% Parathion, 4 oz.	25	0.0	100.0
25% Parathion, 2 oz.	25	24.0	75.0
25% Parathion, 1 oz.	25	44.0	54.2
Check	25	96.0	

[1] All materials are wettable powders.
[2] Sodium lauryl sulfate, 1 oz. per 100 gallons.

FIG. 2.—Injury to grape berries by second brood of red-banded leaf roller larvae.

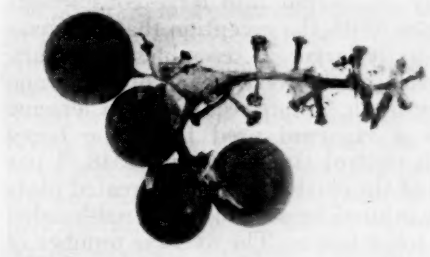

FIG. 3.—Injury on pedicels and peduncle by second brood larvae. Note: Missing berries removed by hand.

table 1 show that dichlorodiphenyl dichloroethane is very effective against the newly hatched leafroller larvae. It appears that it is not only more toxic than DDT but also kills more rapidly. The efficiency of the material was not decreased by a 2-2-100 bordeaux mixture. As applied in these tests, 4 ounces of the actual material in 100 gallons of water gave a kill of 95 per cent or above in from 48 to 60 hours. Eight ounces of actual DDT were required for an equal rate of kill in this time interval.

Comparable spray concentrations of DDT and lead arsenate gave similar results if the time factor is disregarded. Apparently DDT kills more rapidly. Thus as is shown in series 3, table 1, after 60 hours DDT gave 98.1 per cent kill and lead arsenate 37.9 per cent; the kill in 6 days was 98.1 and 95.2 per cent, respectively. In insectory tests Hough (1926) found that 3 pounds of lead arsenate was the minimum concentration for giving 100 per cent kill in 5 days. With 4 ounces of actual DDT, the kill was slightly less than 90 per cent at the time of the 6-day count. Parathion was effective at relatively low concentrations. Since the treated leaf discs and the larvae were kept in closed petri dishes, the kill with sprays containing parathion was probably due partly to fumigation as well as to contact action, especially at the higher concentrations.

The results from the experiment comparing DDT and three analogs of DDT are presented in table 2. Approximately equal numbers of 2- and 3-day-old larvae were used in each test. The highest kill at the end of 72 hours of exposure was obtained with 2 and 4 ounce rates of actual dichlorodiphenyl dichloroethane. Four and eight ounce rates of actual DDT were more effective than methoxychlor or ditolyltrichloroethane at the same concentrations. There was little difference in efficiency between the latter two materials.

The results in table 3 are based on tests

in which 16- and 23-day-old larvae were used. These larvae were reared on grape foliage at a temperature of 68° F. Parathion and dichlorodiphenyl dichloroethane were very effective against these larvae within 48 hours. At the end of 5 days, one pound of actual DDT gave a percentage kill that was comparable to that obtained with 4 ounces of actual dichlorodiphenyl dichloroethane. Lead arsenate at the 4-100 rate was less effective than DDT against these older larvae.

FIELD OBSERVATIONS ON GRAPES.—The earliest account of injury on grapes was published by Slingerland (1904) and was limited to observations on the first brood, This brood webs the blossom buds and newly set berries into large conspicuous masses. With the exception that the mass is usually larger, it resembles the injury by early first brood larvae of the grape berry moth, *Polychrosis viteana* Clemens.

In a vineyard used for grape berry moth control studies during 1948, 4 per cent of the clusters on the untreated plots were injured by second brood red-banded leaf roller larvae. The average number of caterpillars per vine was 2.4 and 1.3, respectively, on the untreated plots and on those sprayed with DDT. All parts of the grape cluster are attacked by the larvae. The surface type of feeding, characteristic of the second brood larvae, is shown on the berries in figure 2 and on the pedicels and peduncle in figure 3. A single larva may damage from one to nine berries; however, the average was 3.1 berries.

SUMMARY.—A method used in obtaining large numbers of egg masses on cellophane is described. Also, an account of the leaf disc procedure employed in testing insecticides against the larvae is presented.

Dichlorodiphenyl dichloroethane was very effective against newly hatched, 2- and 3-day-old and 16- and 23-day-old larvae. There was no apparent decrease in effectiveness of the material when combined with 2-2-100 bordeaux mixture. The analog kills more rapidly than does DDT. Apparently lead arsenate is as efficient as DDT, but the former material kills very slowly. DDT was superior to methoxychlor and ditolyltrichloroethane for killing 2- and 3-day-old larvae. Parathion was very effective at exceedingly low concentrations. Because of the manner in which the treated leaf disc and larvae were handled in these tests, the kill with at least the higher concentrations of parathion was probably by fumigation.

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Control of Plum Curculio on Prunes[1]

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The plum curculio, *Conotrachelus nenuphar* Herbst., is one of the most troublesome pests of prunes in Erie County, Pennsylvania. It is not uncommon to find 25 per cent of the fruit injured by this insect in well-cared-for orchards. For a number of years the accepted methods of control have been two sprays of lead arsenate applied when the beetles are active in the orchards. In recent years the control of the plum curculio has received the attention of a number of workers. Smith (1948), Stearns & Warren (1948), Grayson (1948) Dewey & Van Geluwe (1948), Neiswander (1948) and Driggers & Darley (1949) have shown that benzene hexachloride is more effective than lead arsenate for the plum curculio on peaches. Since sprays of lead arsenate have not been entirely satisfactory for the control of the plum curculio on prunes, experiments were started in 1947 to study the biology and the control of this insect. This paper is a summary of the work for 1947 and 1948.

METHODS AND MATERIALS.—The experiments were conducted in commercial

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prune orchards planted to the variety Fellenberg (Italian Prune). During the season of 1947 tests were carried out in two plantings. Orchard A was 8 rows wide and 20 rows long, and two plots, 8 rows wide and 10 rows long, were established in this orchard. Orchard B was 4 rows wide and 85 rows long. Four plots were established in this orchard. Two plots were 4 rows wide and 25 rows long, one plot was 4 rows wide and 19 rows long and the other plot was 4 rows wide and 16 rows long. In 1948 the tests were conducted in a rectangular block of prunes 12 rows wide and 25 rows long. The test area was divided into 15 plots and each plot was 4 rows wide and 5 rows long. The plots were replicated 3 times and the position of the plots within the blocks were left to chance. The sprays were applied with a power sprayer, using a single nozzle orchard spray gun. All the spraying was done from the ground and from the outside of the tree.

Before the injured prunes started to drop, random samples were collected from the center rows of each plot. Samples were collected at weekly intervals for a period of three weeks. The collected fruits were suspended over water in mesh bags (one-eighth of an inch mesh) and the larvae leaving the fruit dropped into the water. A record was kept of the number of larvae strained from the water.

The materials used in the experiments were as follows: unconditioned lead arsenate, containing 19.50 per cent metallic arsenic and 58 per cent metallic lead; benzene hexachloride,[2] a wettable powder containing 6 per cent of the gamma isomer chlordan,[3] a wettable powder containing 50 per cent chlordan; parathion,[4] a wettable powder containing 25 per cent parathion; benzene hexachloride,[5] a wettable powder containing 25 per cent of the gamma isomer; a miscible oil[6] was used as a spreader; a fixed copper,[7] containing 52 per cent metallic copper and wettable sulfur were used as fungicides.

BIOLOGY.—The emergance of adults from hibernation and the fluctuation of the population were studied by jarring prune trees at two-day intervals throughout the emergence period. In 1947 the first beetles were taken on May 21 and in 1948 the first beetles were found on May 12. In general, the plum curculio can usually be found on prune trees about the time the petals fall, and if warm weather prevails at this time a large number of beetles can be found in the orchards. Usually the greatest number of beetles are present in the orchards for a period of two weeks following petal fall. However, cold weather at this time will delay the emergance of the beetles from hibernation and prolong the emergence period. Although the greatest number of beetles are present early in the season it is not uncommon to find adults throughout the growing season. In 1948 adult plum curculios that were jarred from prune trees late in May, lived throughout the summer and entered hibernating quarters in October.

Life history studies were conducted in the insectary and observations were made in the field on the activities of the plum curculio. In 1947 the first eggs were deposited on June 5 and the larvae were found in the fruit on June 15. In 1948 egg laying started on May 28 and the first larva was found in the fruit on June 11. Rearing records and field observations indicate that only one brood of larvae occurs in Erie County, Pennsylvania. During the seasons of 1947 and 1948 numerous attempts were made to secure second brood eggs. The newly emerged beetles were placed in cages with prunes but no eggs were ever obtained.

CONTROL EXPERIMENTS.—A summary of the results and a list of the treatments are given in tables 1 and 2. In 1947 the experiments were conducted intwo commercial orchards that were heavily infested with plum curculio. The sprays were applied on the following dates: first application at shuck split May 28, second application at shuck fall June 9 and the third spray June 16. As may be seen in table 1, two sprays of lead arsenate did not give satisfactory control of the plum curculio. In orchard A, 49 per cent of the fruit was injured by the curculio and in orchard B, 33 per cent of the fruit was damaged by this insect. There was a light crop of fruit in orchard A and this may have had some influence on the number of injured fruits in this planting. Three sprays of benzene hexachloride gave excellent control of the plum curculio. Ap-

[2] *Gamtox.* California Spray-Chemical Corp., Richmond, Calif.
[3] *Dow Klor.* Dow Chemical Co., Midland, Mich.
[4] *Thiophos 3422.* American Cyanamid Co., New York, N. Y.
[5] *Isotox.* California Spray-Chemical Corp., Richmond, Calif.
[6] *Orthol-V-Soluble.* California Spray-Chemical Corp., Richmond, Calif.
[7] *Basic-Cop.* The Sherman Williams Co., Cleveland, Ohio.

Table 1.—Results of experiments for plum curculio 1947.

Orchard	Test No.	Materials and Amounts per 100 Gallons[1]	Applications	Larvae per 100 Fruits
A	1	Benzene hexachloride, 0.18 pound gamma isomer.	1st, 2nd & 3rd	2
A	2	Lead arsenate, 2.5 lbs.	1st & 2nd	49
B	3	Lead arsenate, 2.5 lbs.	1st & 2nd	33
B	4	Lead arsenate, 2.5 lbs.	1st	
		Benzene hexachloride, 0.18 pound gamma isomer.	2nd & 3rd	2.6
B	5	Benzene hexachloride, 0.18 pound gamma isomer.	1st, 2nd & 3rd	1.8
B	6	Chlordan, 1 lb.	1st & 2nd	8.2

[1] To each 100 gallons of spray was added 1 pound of fixed copper, 2 pounds hydrated lime and 2 quarts of oil.

Table 2.—Results of experiments for plum curculio 1948.

Test No.	Material and Amounts per 100 Gallons[1]	Applications	Larvae per 100 Fruits
1	Lead arsenate, 2.5 lbs.	1st & 2nd	26
2	Benzene hexachloride, 0.18 pound gamma isomer	1st, 2nd & 3rd	1.3
3	Benzene hexachloride, 0.1875 pound gamma isomer	1st, 2nd & 3rd	1.0
4	Parathion, 0.5 lb.	1st & 2nd	0.0
5	Parathion, 0.25 lb.	1st, 2nd & 3rd	0.7

[1] In tests nos. 1, 2 and 3 to each 100 gallons of spray was added one pound of fixed copper, two pounds of hydrated lime and one quart of oil. In tests nos. 4 and 5 to each 100 gallons of spray was added 6 pounds of wettable sulfur.

proximately 2 per cent of the fruit was injured by the plum curculio on the prune trees sprayed with benzene hexachloride. Two applications of chlordan severely injured the foliage and no further sprays were applied. The results indicate that chlordan is not satisfactory for the control of the plum curculio on prunes.

A list of the treatments for 1948 are shown in table 2. The sprays were applied on the following dates: first application at shuck split May 25, second spray at shuck fall June 2 and the third application June 10. As may be seen in table 2, lead arsenate did not effectively control the plum curculio. Three applications of benzene hexachloride gave excellent control of the plum curculio. Parathion when used at the rate of 0.25 pound and 0.5 pound to 100 gallons gave satisfactory control of the plum curculio.

In order to determine the effects of benzene hexachloride and parathion on eggs of the plum curculio a number of prune trees in a neglected orchard were sprayed on June 15, 1948. Parathion was used at the rate of 0.5 pound to 100 gallons with 6 pounds of wettable sulfur. Benzene hexachloride was used at the rate of 0.24 pound of the gamma isomer to 100 gallons with one pound of fixed copper, two pounds of hydrated lime and one quart of oil. At the time the sprays were applied a large number of the fruits were injured by egg punctures of the plum curculio. The day after the sprays were applied a number of injured prunes were collected. From the trees sprayed with parathion 629 fruits were collected and from the trees treated with benzene hexachloride 683 fruits were collected. The collections were suspended over water in mesh bags and the larvae leaving the fruit dropped into the water. No larvae were recovered from the fruit sprayed with benzene hexachloride. From the prunes sprayed with parathion 218 larvae were found. The results of this test indicate that sprays of benzene hexachloride are quite effective against eggs of the plum curculio. Parathion does not appear to be lethal to eggs of the plum curculio. In New Jersey, Driggers and Darley (1949) have shown that benzene hexachloride, at the concentrations ordinarily used, is more effective against eggs of the plum curculio than the adults.

DISCUSSION.—The results of field experiments indicate that sprays of lead arsenate are not entirely satisfactory for the control of the plum curculio on prunes. Additional sprays of lead arsenate for the control of this insect would probably be of value. However, it is questionable whether one would be justified in applying more than two sprays of lead arsenate to prunes as considerable spray injury may result from two applications. Lead arsenate sprays appear to injure the stems of the fruit as well as the foliage and at harvest time it is not uncommon to find twice as many dropped prunes under trees treated with lead arsenate as under trees sprayed with benzene hexachloride. Benzene hexachloride, when used at the rate of 0.18 pound of the gamma isomer to 100 gallons, has given excellent control of the plum curculio. Although benzene hexachloride has a disagreeable odor and taste, and in many instances produces an off-flavor in fruits, the writer has never been able to detect any off-flavor in prunes that have been sprayed with this material. Field experiments indicate that benzene hexachloride sprays are effective against the eggs of the plum curculio. During the season of 1948 parathion gave excellent control of the plum curculio and the re-

sults indicate that this material is as effective for the plum curculio as benzene hexachloride. Sprays of parathion do not appear to be toxic to the eggs of the plum curculio. During the seasons of 1947 and 1948 it has been observed that prune trees that had been sprayed with benzene hexachloride and parathion were not attacked by the mealy plum aphid, *Hyalopterus arundinis* Fabr., whereas prune trees in adjacent plots that had been sprayed with lead arsenate were heavily infested with this aphid. No injury to the foliage or fruit has been observed where benzene hexachloride and parathion sprays were used.

Although chlordan appears to offer some protection against the plum curculio, sprays of this material severely injured the foliage of prune trees. The injury was quite pronounced after the second application of spray. The leaves showed marginal scorch and severe defoliation occurred. The remaining foliage was yellowish in color throughout the season and further growth was inhibited. There was no visible injury to the fruit. However, a large percentage of the fruit dropped before harvest and the prunes that remained on the trees were only about one-half their normal size. In Virginia, Hough (1948) has observed similar injury to plums that were sprayed with chlordan. The results of this experiment indicate that chlordan is toxic to the foliage of prunes and appears to retard the development of the fruit.

SUMMARY.—Life history studies and field observations indicate that there is only one brood of plum curculio larvae in Erie County, Pennsylvania. The adults appear in prune orchards about the time the petals fall. If warm weather prevails at this time the greatest number of beetles are present in the orchards for a period of two weeks following petal fall.

Control experiments indicate that three applications of benzene hexachloride, used at the rate of 0.18 pound of the gamma isomer to 100 gallons, will satisfactorily control the plum curculio. Tests for one season indicate that three sprays of parathion, used at the rate of 0.25 pound to 100 gallons, will give excellent control of the plum curculio. No injury to the fruit or foliage of prunes has been observed where sprays of benzene hexachloride and parathion were used. No off-flavor to the fruit could be detected in prunes that were sprayed with benzene hexachloride. Lead arsenate does not appear to give satisfactory control of the plum curculio on prunes. Two applications of chlordan severely injured the foliage of prunes and retarded growth of the tree and development of fruit.

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Pear Psylla Control with Parathion[1]

W. J. O'Neill[2,3]

Inspection of pear orchards in the Entiat valley of North Central Washington in the spring of 1948, disclosed a high level of pear psylla population. Promising control of pear psylla, *Psylla pyricola* Foerst., with parathion have been reported by Newcomer (1947) and Hamilton (1948). The objective of the following experiment was an evaluation of parathion for pear psylla control in North Central Washington.

A ranch near Entiat, Washington, was selected as the site of the experiment. The experimental orchard consisted of a four acre block of D'Anjou pears with Bartlett fillers. Blackened buds, fruit spurs and twigs, in this block, indicated a severe psylla infestation had occurred in 1947. The block was divided into three plots of approximately 70 trees per plot and numbered 1, 2 and 3, west to east. An additional pear block, located 200 yards west of plot 1 in the general orchard, was later introduced and numbered plot 4 and used as a check plot.

Sticky Board Trap Population Studies.—Ten board traps (Davis 1944) were placed in 10 trees in plots 1, 2 and 3, respectively, March 18. On April 7, the board traps were removed from plots 1 and 2 and adult psyllas recorded. The close agreement in the number captured per plot indicated a comparable infestation despite the rather wide variation in psyllas per individual board. Individual board records have been omitted in this paper for brevity. The numbers of psyllas captured during this period are shown in table 1.

Plot 1 was sprayed April 7 (Table 2). Traps were replaced in plots 1 and 2 on April 8 and exposed until June 8. Psyllas captured in plots 1, 2 and 3 during this exposure period showed a significant reduction in the number captured in the sprayed plot. Plots 1, 2 and 3 were sprayed June 12. Traps were placed in plots 1, 2, 3 and 4 on June 21 and exposed until October 1 when the final trap record was taken. The trap records for the final exposure period were influenced by the spray programs. In plot 4, the nicotine-oil spray and the parathion spray materially reduced the psylla infestation in this plot. Psyllas captured in plots 1, 2 and 3 are, in the authors opinion, largely the result of migration from plot 4. Plot 1, closest to plot 4, showed the greatest number captured.

Table 1.—Adult psyllas captured on 10 board traps.

Exposure Period	Plot 1	2	3	4
March 18 to April 7	339	353	—	—
April 8 to June 8	409	3040	2654[1]	—
June 21 to October 1	980	551	426	1266

[1] The exposure period for plot 3 was March 18 to June 8.

Caged Psylla Tests.—Cloth-covered cages were used in an attempt to determine the effect of parathion sprays on adult psylla. The cages were 36 by 26 by 15 inches in dimension, and covered with a fine grade of organdy cloth. Just prior to the first spray (April 7), a cage was suspended from large horizontal leaders in plots 1 and 2. Five hundred adult psyllas were collected and placed in each cage. Plot 1 was then sprayed with 1 pound of parathion (25 per cent). Spray drift was permitted to wet the cloth covering of the cage in the sprayed plot thoroughly.

Mortality counts, made at the end of 24 hours, April 8, showed 100 per cent mortality in the sprayed cage with no mortality in the unsprayed cage suspended in plot 2.

The dead psyllas were removed from the sprayed cage and 500 more newly collected psyllas were placed in the cage. A second cage, not contaminated with spray, was suspended in the sprayed plot 1 and 500 newly collected psylla liberated therein.

Examination of the cages at the end of 24 hours, April 9, again showed 100 per cent mortality of psyllas in the sprayed cage in plot 1, 10 to 15 per cent mortality in the clean cage in plot 1 and little or no apparent mortality in the clean cage in the

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unsprayed plot. The dead psyllas were removed from the sprayed cage and 500 other psyllas replaced them in the cage.

Examination, at the end of 24 hours, April 10, showed approximately 50 per cent mortality in the sprayed and unsprayed cages in plot 1 and less than 5 per cent mortality in the clean cage in the unsprayed plot. Examination, at the end of another 24-hour period found live psyllas present in all three cages, with lowest mortality in the clean cage in the unsprayed plot. Examined on April 12, 100 per cent mortality of psyllas had occurred in the sprayed cage, but live psyllas were present in the other cages. Two hundred newly captured psyllas were liberated in the sprayed cage after removal of the dead psyllas. Examination at the end of another 24-hour period, April 13, showed low mortality in the sprayed cage and live psyllas still present in the clean cage in the unsprayed plot. Mortality was 100 per cent in the clean cage in the sprayed plot, thus 100 per cent mortality resulted in the clean cage in the sprayed plot within 120 hours. Examination on April 14 showed live psyllas were present in both of the remaining cages and the final examination, April 15, showed 100 per cent mortality for both cages, thus 162 hours were required for 100 per cent mortality of adult psyllas confined in a clean cage in the unsprayed orchard, 120 hours in the clean cage in the sprayed orchard and, in the sprayed cage, 100 per cent mortality occurred within 24 hours for the first 2 days after spraying. Thereafter, the period for 100 per cent mortality was longer.

Chemical analyses of parathion spray deposits have indicated a rapid loss of parathion by volatization for the first few days following a spray application, followed by a slower rate of loss. These limited data are in general agreement with such chemical studies and suggest that parathion acts both as a contact poison and as a fumigant in the reduction of adult psyllas. Had the psyllas in the clean cage in the sprayed orchard been exposed to the fumigation effect during the first 24 hours following the spray, the period required for 100 per cent mortality probably would have been shorter.

EGG AND NYMPH STUDIES.—An examination of the orchard was made April 19 and no nymphs were found, indicating that no appreciable hatching of psylla eggs had occurred up to this date. An examination made April 21, found numerous newly hatched nymphs present on the opening buds. It was also observed that blossom stems and the unfolding leaves bore numerous newly deposited eggs.

On April 23, a careful examination of the new growth on 50 buds from both the sprayed and the unsprayed plots was made. Since this new growth had occurred subsequent to the spray application April 7, it was believed that a count of eggs on new growth, at this date, would afford an acceptable evaluation of the control of adults with the early spray. No eggs, nymphs or adults were found on the 50 buds examined in the sprayed plot, whereas 935 eggs, 10 nymphs and 5 adults were found on the 50 buds examined in the unsprayed plots.

Table 2.—Spray program, McArthur Ranch, Entiat.

Plot No.	Spray, Date of Application and Strength of Material			
	First	Second	Third	Fourth
1	Parathion[1] 1 lb. (4/7)	DDT[2] 2 lbs. Parathion[1] 1 lb. (6/12)	DDT[2] 1 lb. Parathion 1 lb. (7/14)	—
2	—	DDT 2 lbs. Parathion[1] 1 lb. (6/12)	DDT 1 lb. Parathion 1 lb. (7/14)	—
3	—	DDT 2 lbs. Parathion 1 lb. (6/12)	DDT 1 lb. Parathion[1] 1 lb. (7/14)	
4	Dormant oil 5 qts. Lime sulphur 3 gals. (4/10)	DDT 7 lbs. Dinitro compound 4 oz. (6/12)	Nicotine sulphate 12 fl. oz. Petroleum oil 2 qts. (7/13)	DDT 1 lb. Parathion[3] 4 oz. (8/15)

[1] *Thiophos*, parathion 25 per cent, American Cyanamid Co. used in all tests except the spray applied to the fourth plot on August 15.
[2] *Genitox*, 50 per cent wettable DDT powder, General Chemical Co. used in all tests.
[3] *Genithion*, parathion 15 per cent wettable powder, General Chemical Co.

Absence of psylla eggs on the new growth in the sprayed plot could be attributed to adult psylla mortality from the spray, but nymphs should have been found since eggs had been found equally numerous on the fruit spurs and twigs in both the sprayed and the unsprayed plots prior to the application of the spray. An examination of fruit spurs, under a binocular microscope, showed psylla eggs were hatching normally on the unsprayed spurs whereas, on the sprayed spurs, the eggs were either shrivelled, wrinkled or abnormally turbid and darkened in appearance with no evidence of hatching.

If parathion were causing mortality of psylla eggs, examination of leaves for nymphs should have shown a significant difference in the number of nymphs present. Consequently, 200 leaves were collected June 2 in the sprayed plot 1, and unsprayed plots 2, 3 and 4, and the nymphs and eggs counted under a binocular microscope. Later counts were reduced to 100 leaves per plot. These data are presented in table 3.

Reference to the spray program (Table 2) is necessary in discussion of the data presented in table 3. The leaves collected June 2 show the suppression of pear psylla in the sprayed plots 1 and 4 whereas the unsprayed plots 2 and 3 show nymphs and eggs sufficient for a serious infestation. Leaves collected July 9 to 12, show a reduction of the nymphal population to a low level in all parathion sprayed plots. A significant increase in both nymphs and eggs occurred in plot 4 at this time. Counts of numphs and eggs made July 28 to 30, show nymphs at the vanishing point in the parathion plots. Approximately a 50 per cent reduction in plot 4 resulted from the oil-nicotine spray. The final counts of nymphs and eggs, September 3 to 8, show no record of nymphs in any plot. The infestation in plot 4 had become serious, but was suppressed with parathion in August. The number of eggs in comparison with nymphs, in the parathion plots, is not readily explained. The author suggests that inter-orchard and inter-plot migration of pear psylla is greater than generally recognized. Thus, psyllas migrate into the orchard or plots and lay eggs. Subsequent parathion sprays kill the eggs, but this is not apparent unless sufficient time elapses before the counts are made.

Table 3.—Psylla nymphs and eggs per leaf sample.

	Nymphs				Eggs			
	Plot Numbers							
Date	1	2	3	4	1	2	3	5
6/2	5	155	172	7	33	125	231	3
7/9–12	0	0	4	36	32	27	120	34
7/28–30	1	0	0	18	30	22	18	15
9/3–8	0	0	0	0	0	3	2	20

Table 4.—Codling moth injury and psylla-marked fruit from samples of 2400 fruits from each plot, expressed as per cent injured.

Plot	Wormy	Stung	Psylla-marked
1	0	0	0.96
2	0.12	0.20	0.07
3	0	0.20	0.20
4	0.07	0	83

Harvest Records.—A pear psylla control program has as its objectives (1) prevention of devitalization of the tree from the feeding of the insect and (2) prevention of injury to foliage and fruit caused by the secretion of copious amounts of honeydew by the insect. Psylla honeydew causes a necrosis of that part of the pear leaf it covers and on the fruit, serves as a medium for the development of a sooty fungus impossible to remove. Some orchards in Chelan County, Washington, suffered a 50 per cent loss of marketable fruit due to pear psylla in 1948.

The spray programs reported in this experiment were designed for the control of all orchard insects and mites attacking pears in north central Washington. At harvest, 200 fruits per tree were examined on each of 12 trees per plot and the fruit scored as codling moth injured psylla marked or clean. The complete spray program employed, together with the harvest records, are presented in tables 2 and 4.

Culls were analyzed in plot 4, in which they accounted for 10 per cent of the harvested crop, and graded for pear psylla damage. Thirty-eight per cent of the crop graded extra fancy, 14 per cent was reduced to fancy grade and 48 per cent was reduced to culls. Psylla markings on the fruits in plots 1, 2 and 3 did not affect grade. It is of interest that plot 1 had the greatest number of psylla-marked fruits; caused, in the author's opinion, by its proximity to plot 4.

PARATHION RESIDUES.—Acknowledgment is made to K. C. Walker, Assistant Chemist, Tree Fruit Experiment Station, for his chemical analysis of parathion residues. Pear samples were collected at harvest, September 21 and analyzed October 2, a period of 99 days from the last spray application to harvest. Parathion residues were reported as: plot 1=0.05 PPM, plot 2=0.10 PPM, and plot 3=0.04 PPM.

SUMMARY.—Experiments were conducted for the control of pear psylla in the Entiat Valley of Chelan County, Washington, in 1948. Parathion sprays resulted in excellent control of pear psylla. Parathion acts as a contact spray and fumigant on the adult psylla, is effective as a contact spray on the nymphs and is an effective ovicide on psylla eggs. For maximum control, it is suggested that all pear trees within the infested area be sprayed at approximately the same date in order to minimize inter-orchard migration of adult psylla.

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An Ethylene Dibromide-Chlordan Mixture to Control Soil-Inhabiting Stages of the Japanese Beetle

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The results of preliminary investigations of ethylene dibromide in aqueous solutions for the control of the soil-inhabiting stages of the Japanese beetle, *Popillia japonica* Newm., have been reported by Mason & Chisholm (1945). Their studies demonstrated that ethylene dibromide is highly effective but that certain kinds of plants cannot tolerate the concentrations required to kill the various stages of the beetle. The authors (1946) also observed that an emulsion of an ethylene dichloride solution of chlordan applied to turf, was toxic to Japanese beetle grubs in the soil. The effectiveness of chlordan when applied as a dust on turf was demonstrated by Fleming (1947). Investigations of ethylene dibromide-chlordan mixtures containing reduced amounts of each insecticide to lessen the hazard of plant injury were started in 1947. The results of these studies are reported in this paper.

MATERIALS AND METHODS.—The toxicants were formulated separately or together as emulsible mixtures, which were diluted with water for testing. In the diluted formulations the ethylene dibromide was in aqueous solution and the chlordan was dispersed as an emulsion of very small particle size. The ethylene dibromide-chlordan formulation described by Chisholm & Mason (1948) was used in all but the preliminary tests. Its formula is as follows:

	Per Cent (by weight)	Ounces (approx.)
Ethylene dibromide	13.0	16
Chlordan (technical)	6.5	8
Cellosolve[2]	6.5	8
Emulsifier[3]	6.5	8
Isopropyl alcohol (99%)	67.5	To make 1 gallon

The ingredients are mixed in the order given to form a clear dark-colored mixture. The formulation is diluted for use by pouring the product into water. The emulsion that is formed is easily dispersed with moderate stirring.

The diluted formulation was used either as a dip or as an application to the surface of infested turf. The dip was prepared by adding 3 ml. of the concentrate to 1 gallon of water. Dipping involved the immersion of plant or soil balls in the diluted formulation until they were thor-

[1] The authors are indebted to L. W. Coles and H. W. Strabel for assistance throughout these investigations.

[2] Ethylene glycol monoethyl ether.

[3] A polyoxyalkylene derivative of sorbitan monolaurate.

oughly soaked, or until air bubbles ceased to escape. The plant balls were similar to those prepared for shipment from nurseries and contained the root systems of plants and the soil naturally adhering to them. They were 8 to 10 inches in diameter. The artificial soil balls were prepared by compacting soil into screen-wire forms to simulate plant balls. The soil balls were either 4 or 8 inches in diameter. For the turf treatments the surface of infested plots was sprinkled with different amounts of various dilutions of the stock formulation.

PRELIMINARY TESTS.—In preliminary tests a mixture of the two toxicants was lethal to the soil-inhabiting forms of the Japanese beetle immediately after its application, and this toxicity lasted for several weeks. When the concentrations of ethylene dibromide mentioned by Mason & Chisholm (1945) were greatly reduced and chlordan was added, the insecticidal value of the mixture was equal to that of higher concentrations of ethylene dibromide. The toxicants likewise proved to be more effective when combined than when used separately.

EFFECTIVENESS OF DIPS.—When soil balls and artificial plant balls (soil temperatures 65° to 80° F.) containing eggs were dipped in the 3-ml. dilution, less than half of the eggs hatched when they were left in the treated soil for 1 day. In most of the tests none of the eggs survived a 7-day exposure period in the treated soil. No living eggs or larvae were found in treated balls left undisturbed for 3 weeks.

When third-instar larvae were left in treated soil balls and plant balls (60° to 80° F.) for 1 to 14 days and were then removed, all the larvae died within 7 days after their removal.

Third-instar larvae inserted into soil balls at intervals up to 21 days after treatment were killed during a 14-day period in the treated soil. Although most of them were obviously dead on removal, final mortality observations were delayed until decomposition began. Recently hatched first-instar larvae died within 5 days after they were placed in soil from plant balls that had been dipped as long as 4 weeks previously.

Third-instar larvae were also inserted into plant balls that were not treated until the larvae had pupated. The balls were then dipped in the 3-ml. dilution and held in screened cages for 15 days at temperatures ranging from 70° to 80° F. A few beetles emerged during the first 2 days after treatment. The beetles seemed to be moribund, and they died within 48 hours after their emergence. No living pupae or adults were found when the balls were broken down at the end of the 15-day period.

Adult beetles in wire cages were buried in soil balls, which were then dipped in the 3-ml. dilution. After 24 hours the beetles were removed and placed in clean cages. All of them died within 3 days.

EFFECTIVENESS OF APPLICATIONS TO THE SURFACE OF INFESTED TURF.—Screen cages were placed over square-yard plots of turf and about 3,000 beetles were placed in each cage. After the beetles had been allowed 5 days in which to oviposit, they were removed from the cages. Each plot was then sprinkled with 20 or 30 ml. of the stock formulation in 1 or 2 gallons of water. Three weeks later there were 1,680 first-instar larvae in the untreated plots, but only 1 grub was found in the treated plots.

Square-yard plots having natural populations of 150 to 500 third-instar larvae (usually about 300) were treated with 5, 10, or 15 ml. of the formulation, each in 8, 4 or 1 quart of water, on April 22 (3-inch soil temperature 56° F.) and on May 10, and 26 (3-inch soil temperature 65° F.). Five to 7 after days treatment, the larvae were dug out of the plots, transferred to fresh soil, and then held for periods up to 2 weeks while mortalities were being recorded. None of the larvae survived in the plots treated with either 5 ml. or 10 ml. of the stock formulation in 8 quarts of water. The same amounts of the stock formulation in 1 gallon of water were less effective. In 6 plots totaling 6 square yards, one larva survived an application of 15 ml. in 4 quarts, and 1 or 2 larvae survived an application of 10 ml. in 4 quarts. The mortality ranged from 80 to 100 per cent in the plots treated with 5 ml. of the stock formulation in 4 or 8 quarts, and with 5, 10, and 15 ml. in 1 quart of water.

Square-yard turf plots having an estimated population of 200 pupae per plot were treated with 20 or 30 ml. of the stock formulation, each in 4 or 8 quarts of water. Some of the plots were treated when the

pupae were newly formed, and others when adult beetles were beginning to emerge. After treatment the plots were covered with screen-wire cages, and beetle emergence was recorded for 2 weeks. At the end of this period the soil was examined for adults and pupae.

In the tests with newly formed pupae no beetles emerged, and no living beetles or pupae were found in the soil that received 30 ml. of the stock formulation in 4 or 8 quarts per square yard. From 1 to 16 living beetles and pupae were recovered from the plots treated with the 20-ml. dilution. In the tests with puape about ready to complete their transformation, from 2 to 8 beetles emerged from the soil that received 30 ml. of the stock formulation in 4 or 8 quarts per square yard, and from 1 to 5 from the soil treated with 20 ml. in 4 or 8 quarts. A few living adults were also found in the soil in these plots. The 4- and 8-quart applications appeared to be equally effective. In all plots many of the beetles that emerged appeared to be in a weakened condition, and many of them died in the cages within a day or two.

Effect of Treatments on Plants.—Plant balls containing many varieties of plants were dipped in ethylene dibromide-chlordan mixtures by several nurserymen and then held for observation to determine plant reaction. These tests are still in progress, but no injury has yet been reported. No injury to turf has been observed when the applications did not exceed 20 ml. of the stock formulation per gallon per square yard. A temporary yellowing of the grass occurred in some plots that received 30 ml. in 1 gallon per square yard.

Discussion.—Since dipping in the 3-ml. dilution of the ethylene dibromide-chlordan concentrate disinfested plant balls at temperatures above 60° F. of all stages of the Japanese beetle, the use of this procedure under specified conditions has been approved (1948) as a Japanese beetle quarantine treatment. Balled or potted plants can now be shipped to points outside the restricted area at any time of year. The treatments previously authorized had to be applied when larvae only were in the soil.

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Field Tests of Insecticides and Spraying Methods to Control Horn Flies in Dairy Herds[1]

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During 1947 the more recently developed chlorinated hydrocarbon insecticides were tested as horn fly control agents, in the laboratory and in the field, by workers of the Bureau of Entomology and Plant Quarantine at Kerrville, Texas, All the treatments were sufficiently persistent to eradicate horn fly infestations in the herds at the time of treatment. The interval between treatments was dependent upon movement of flies into the treated herds and the favorableness of conditions for fly build-up.

Eddy & Graham (1949) treated cattle, released them in a pasture, and periodically confined them in screen cages where they were exposed to horn flies, *Siphona irritans* (L.), from a laboratory colony. They established that DDT was the most effective of the materials tested although from the standpoint of persistence alone, toxaphene was about equally effective. Water suspensions containing 0.5 per cent of these insecticides, when applied over the entire bodies of experimental cattle, persisted as effective residues for 3 weeks.

[1] The writer expresses sincere appreciation to J. M. Driess who conducted the spray applications and made field records.

Methoxychlor, dichlorodiphenyl dichlorothane and chlordan were somewhat less effective.

Smith (1949) treated dairy cattle in the vicinity of Kerrville and found that it was necessary to re-treat the herds at approximately monthly intervals when DDT, toxaphene, and chlordan were used as residual insecticides. Dichlorodiphenyl dichloroethane and methoxychlor had to be reapplied at intervals of approximately 3 weeks.

Laake (1949) obtained good control of horn flies when he applied the new insecticides on range cattle in Kansas and Missouri. In general, in Kansas the treatments had to be reapplied at approximately monthly intervals, whereas in Missouri resprayings were necessary about every 6 weeks. It has been established that DDT and dichlorodiphenyl dichloroethane and possibly the other residual insecticides, are excreted in the milk of cattle sprayed with those materials. The experiments described in this paper were set up in 1948 for the purpose of measuring the effects of different methods of spraying on horn fly control and on insecticide contamination of milk. Only those phases which relate to insect control are discussed in this paper.

MATERIALS AND METHODS.—The insecticides used were DDT, dichlorodiphenyl dichloroethane, methoxychlor, and toxaphene. All the materials were formulated in the laboratory as emulsion concentrates of the following composition: Insecticide 25 per cent, xylene 65 per cent, an aralkyl polyether alcohol[1] 10 per cent. The emulsion concentrates were diluted with well waters in the field to a concentration of 0.5 per cent.

Each insecticide was sprayed on four different herds (average 32 cows per herd) of grade Jersey cows as follows: (1) 2 quarts (containing approximately 9.5 grams of insecticide) over the entire body of each animal, (2) 1 quart over the entire body, (3) 1 quart over the dorsal half of the body (top line spraying), and (4) 1 quart over the ventral half of the body (bottom line spraying). The treatments were applied in dairy barns on animals confined in their stanchions. Spraying was done with a nozzle pressure of approximately 200 pounds per square inch.

All 16 herds were located in the vicinity of Kerrville. Treatments were initiated in June and were continued as frequently as necessary until frost terminated fly activity in November.

Horn fly populations were estimated by making counts of flies on several animals in each herd. These counts were made either early in the morning or late in the afternoon, when temperature conditions were such that flies were in readily visible locations. When the first treatments were applied, the fly counts averaged 25 or more per animal in every herd. Thereafter all herds were inspected twice weekly and as fly populations built up to an average of 25 per animal, treatments were reapplied on the following day.

RESULTS.—The results of these experiments are summarized in table 1.

As indicated by the wide variation in range in number of days between retreatment, the protection varied greatly. Much of this variation was due to a drought which prevailed in the vicinity of Kerrville during much of the summer and to other weather conditions that were unfavorable for horn flies. Beginning in September, localized thunder showers made conditions favorable for fly increase on some dairy farms, whereas no rain fell on others. There was general rainfall be-

Table 1.—Control of horn flies on dairy cattle sprayed with emulsions containing 0.5 per cent of insecticide.

Area Treated	Quarts per Animal	Treatments	Days Protection	
			Average	Range
		DDT		
Top line	1	3	49	23– 95
Under line	1	6	32	14– 63
Entire body	1	3	37	37–112
	2	2	—[1]	
			41[2]	
		Methoxychlor		
Top line	1	4	37	17–105
Under line	1	5	29	14– 70
Entire body	1	3	53	21–144
	2	3	51	21–155
			40[2]	
		Dichlorodiphenyl dichloroethane		
Top line	1	5	28	16– 63
Under line	1	6	28	15– 76
Entire body	1	4	40	27–101
	2	4	42	22–115
			34[2]	
		Toxaphene		
Top line	1	4	37	17– 71
Under line	1	4	38	21–104
Entire body	1	5	29	23– 48
	2	5	30	21– 50
			34[2]	

[1] Triton X–100.

[1] Second spraying was applied just before frost.
[2] Average of all treatments.

ginning in October, and during the last month of the season weather conditions favored an increase of horn flies.

Because of the variation in conditions during the summer season and the differences in local showers between farms, the various treatments are not easily compared. The average protective period for the 2-quart spraying of all four insecticides was considerably greater than that reported by Smith (1947) in his work on these same dairy herds in 1947 when rainfall was more abundant. Where weather conditions were favorable for fly activity the protective period for 2-quart spray applications was similar to that noted by other workers of the Kerrville laboratory for the 1947 season.

The figures in table 1 showing minimum periods of protection (under Range) illustrate the relative efficiency of the different treatments better than do the averages, which reflect the influence of abnormal weather conditions.

The data in the table do not indicate any real differences between the insecticides; neither do they show important differences in protection between methods of application. However, with all the insecticides except toxaphene, fly-free periods were diminished when the herds were sprayed on the under line only.

Conclusions.—The data indicate that, when any of the four chlorinated hydrocarbon insecticides are applied to Jersey cattle for horn fly control, 1 quart of 0.5 per cent spray eradicates the horn fly population in the pasture at the time of treatment; it is not advantageous to use twice as much spray; and that 1 quart sprayed over the top half of the body results in as satisfactory control as 1 or 2 quarts sprayed over the entire body.

Summary.—During the summer of 1948 experiments were conducted for the control of horn flies, *Siphona irritans* (L.), on dairy herds in the vicinity of Kerrville, Texas. Four chlorinated hydrocarbon insecticides—DDT, methoxychlor, dichlorodiphenyl dichloroethane and toxaphene—were compared. Each insecticide was applied as a 0.5 per cent emulsion to four herds of grade Jersey cows as follows: (1) 2 quarts of spray over the entire body, (2) 1 quart of spray over the entire body, (3) 1 quart over the dorsal half of the body (top line), and (4) 1 quart over the ventral half of the body (under line).

Drought conditions unfavorable for horn fly increase caused considerable variation in the results. However, records made during periods of favorable weather were in accord with those obtained by other workers of the Kerrville laboratory during the 1947 horn fly season.

The performances of the four insecticides were similar. The protective values were about equal, whether 1 or 2 quarts of the insecticide were applied over the entire body or 1 quart over the dorsal half of the cow's body. When herds were sprayed on the under line only, fly-free periods were diminished.

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Effect on Horse Fly Populations of Aerial Spray Applications to Wooded Areas

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In many areas of the United States horse flies are among the most severe pests of livestock. During seasons when they are unusually abundant, many acres of good pasture are rendered useless because livestock will not graze satisfactorily where horse flies are numerous. Unfortunately, no satisfactory control measures are available. Since the advent of the new chlorinated hydrocarbon insecticides, it has been suggested that their application to the resting places of horse flies might provide a useful and economical control measure. A cooperative experiment was conducted by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture, the Oklahoma Agricultural Experiment Station, and the National Livestock Loss Prevention Board to test the effectiveness of materials applied to the resting places of the flies by aircraft.

Location of Test Areas.—The work was done in the Lake Carl Blackwell area of the Oklahoma Agricultural Experiment Station's animal husbandry pastures This land had once been cultivated, but was terraced and returned to grass between 1936 and 1939. The water flow in the stream is intermittent, but a few natural pools and artificial farm ponds contain water the year round. The heavily wooded borders of these streams form narrow belts of trees between almost treeless rolling pastures. Four test plots and two check plots were set up along the streams. Five of the plots were of 10 acres each, and the sixth was about 60 acres. These areas appeared uniform from the air and ground. Although the flies were more abundant in some plots than in others, they were considered sufficiently numerous in all plots to conduct the tests under consideration.

Materials and Methods.—The test insecticides were methoxychlor, toxaphene, chlordan, and DDT. The insecticides, at 10 per cent concentration, were dissolved in a mixture of No. 1 fuel oil and cyclohexanone. To facilitate checking the spray pattern and particle size, 0.5 per cent of an oil dye[4] was added to the mixture.

The solutions were applied at the rate of 2 pounds of toxicant per acre by a plane equipped with a standard spray boom. Flights were made at 5 to 20 feet above the tree canopy while the wind velocity was less than 3 miles per hour. To determine the spray pattern, graph paper and slides coated with magnesium oxide were placed in rows at right angles to the direction of flight. Particle size was determined by microscopic measurement of the magnesium oxide droplet "craters." Weather records were obtained from the official station on the area.

The effectiveness of the spray materials was determined by counting the flies on draft horses led through the wooded areas on the day preceding spraying and 1, 2, 3, 5, and 7 days after treatment. As a check, fly populations were also determined in an unsprayed plot and in a plot sprayed with cyclohexanone and fuel oil only. Cattle had access to all areas at all times during these tests and in a few instances were observed in the wooded areas during counting periods.

Four men made the fly counts each day. Horses pastured on the area were haltered and led along the banks of the stream. At 5-minute intervals each animal was stopped and all horse flies present were counted and recorded according to species. A few species of *Chrysops* and *Silvius* were present, but in negligible numbers. No attempt was made to free the horse of flies before starting, nor were the flies that were feeding between stops counted. In so far as possible, counting was started and ended at the same time each day, in an effort to minimize variations in population. Counts were made over a period of approximately 2 to 3 hours in the morning and over about the same period in the afternoon.

The methoxychlor solution was applied between 5:15 and 5:30 A.M. on August 12, 1948. Weather conditions were excellent and the spray pattern obtained was good. Because of a dense fog that came

[1] Oklahoma Agricultural Experiment Station.
[2] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine.
[3] National Livestock Loss Prevention Board.
[4] du Pont oil red.

up suddenly and did not dissipate until 3 P.M., it was not possible to continue the morning flight. Therefore the DDT, toxaphene, and chlordan treatments had to be applied between 5 and 6:30 P.M. Afternoon spraying conditions were less satisfactory, but coverage was considered good. The check area receiving the carriers alone was sprayed the following evening, when conditions were satisfactory. All graph papers and slides showed drops averaging one-eighth-inch or less apart, and no area larger than one-fourth inch square was missed. The mean particle size was 58 microns, the mode of particle size was approximately 20 microns.

Possible hazards to wildlife were evaluated by F. M. Baumgartner and associates of the Zoology Department, Oklahoma A. & M. College. They inspected the areas one day before spraying and the first, second, and fifth days after spraying. All the vertebrate animals seen or heard were counted and estimates were made of the invertebrate fauna. Animals observed on the buffer strips 200 feet wide around the margins were included in the counts.

RESULTS.—Apparently spraying was done at the fly-population peak, because fly numbers decreased in all plots except the area treated with methoxychlor. The average number of flies per count in the methoxychlor plot 24 hours before treatment was 2.6, and 7 days after spraying it was 3.3. This increase was due largely to an increase of one species, *Tabanus abactor* Phil.[1] A considerable reduction in the number of flies was noted in the plots treated with DDT, toxaphene, and chlordan. (Table 1.)

The number of flies in the untreated control decreased only slightly during the experiment. At the beginning of the test the average number of flies per count was 3.7, and 7 days later the counts averaged 2.4. The population of flies in this area was very similar to the population present in the plot treated with methoxychlor.

The second control, which was sprayed with the carrier, showed a decrease in the number of flies similar to that in the plots treated with DDT, toxaphene, and chlordan. However, it is pointed out that this plot was sprayed a day later than the other areas, and the decline in fly population from an average of 15 flies to 10 per stop, which occurred at the beginning of the experiment, actually took place before the spray was applied. The decline, therefore, could not be attributed to the carrier. Whether the fly population would have built back up to an average of 15 or to an average of 10 flies per stop, as it was at the beginning of the test, had no spray been applied is, of course, problematical, Had it not been for the decline of flies in this particular control, the writers could have concluded that a considerable reduction of flies was caused by all the insecticides except methoxychlor.

Table 1.—Average numbers of horse flies recorded at 5-minute intervals on horses led through test plots before and after treatment.

TREATMENT	1 DAY BEFORE TREATMENT	DAYS AFTER TREATMENT				
		1	2	3	5	7
Methoxychlor	2.6	2.8	3.7	3.2	3.0	3.3
DDT	13.8	5.9	4.4	4.7	1.0	4.8
Toxaphene	2.5	2.6	.7	.8	.3	.4
Chlordan	11.9	6.2	3.2	2.3	2.6	6.5
Control, untreated	3.7	2.6	2.7	3.1	2.0	2.4
Control, treated[1]	15.0	10.0[2]	4.4	3.4	3.2	5.2

[1] Treated with a mixture of cyclohexanone and fuel oil on the day after the other plots were sprayed.

[2] The spray was applied shortly after this figure was obtained, so that the subsequent averages were actually obtained 1, 2, 3, and 5 days after treatment. The figures were left in line with the other data in the table, since they were obtained at the same time.

Tabanus abactor and *T. sulcifrons* Macq. were abundant, whereas *T. atratus* F., *T. vittiger* Thoms., *T. mularis* Stone, and *T. venustus* O. S. averaged less than 1 fly per stop. Before the spraying the average per stop was 3 for *T. abactor* and 4.5 for *T. sulcifrons*. These species decreased to lows of 0.7 and 0.8, respectively. Other flies were not numerous during the test. Individual counts were much higher than the average. A maximum of 31 flies was reached and counts above 25 were common.

The influence of weather on the fly population is not clear. Temperature and rainfall appeared to be the most important factors. The greatest number of flies were found on a warm day following 2 days of rainfall and a week of cool weather, and the smallest number on the coldest day. Wind velocities never averaged over 9 miles per hour during the counting, and no influence of wind could be demonstrated.

No significant effect of the toxicants on the warm-blooded animals was noted.

[1] The flies were determined by Alan Stone, Bureau of Entomology and Plant Quarantine.

Numerous dead grasshoppers were especially noticeable in the plots treated with chlordan and toxaphene.

DISCUSSION.—Many workers have tested the effects on tabanids of the new insecticides when sprayed on host animals, but few have reported satisfactory control. Since the time spent by a horse fly on the host is short, it seemed logical to assume that better control might be obtained if the resting places of the flies were treated, so that the flies would be in contact with the toxicant a much longer time. It is believed that most horse flies rest in trees, or in heavy brush if it is available. Livestock are more readily attacked in woody or shrubby areas during daylight hours and seldom enter such places if it is possible to avoid them. Because cattle seldom grazed in the fly belts and grass was very scanty there, it appeared that there would be little danger of residual poisoning if the wooded areas between upland pastures were sprayed. However, the results of the tests were not encouraging, since no appreciable control could be demonstrated with any material tried. Previous work indicated that the small species of horse flies were more easily controlled then the large species, but no evidence was obtained to support this conclusion.

SUMMARY.—The effect on horse fly populations of aerial sprays applied to wooded areas was studied. Ten-acre plots were treated with 2 pounds per acre of one of the following insecticides, dispersed in a mixture of cyclohexanone and No. 1 fuel oil: methoxychlor, DDT, toxaphene, and chlordan. The effectiveness of the materials was determined by counting flies attacking draft horses led through the test plots 1 day before spraying and 1, 2, 3, 5, and 7 days after treatment.

The results appeared somewhat erratic, and no appreciable effect on fly populations could be demonstrated for any of the insecticides tried.

Tabanus abactor and *T. sulcifrons* were the two most abundant species. *T. atratus*, *T. vittiger*, *T. mularis*, and *T. venustus* were present in small numbers. A few species of *Chrysops* and *Silvius* were also present.

The Viability of Seeds Fumigated with an Acrylonitrile-Carbon Tetrachloride Mixture[1]

E. H. GLASS and W. F. CROSIER,[2] *Cornell University, Geneva, N. Y.*

A mixture of equal volumes of acrylonitrile (CH_2CHCN) and carbon tetrachloride (CCl_4) has recently become available as a commercial fumigant.[3] It has been used primarily for the control of insects in such stored products as flour, wheat, and tobacco. Acrylonitrile is also known to be toxic to certain other insects (Glass 1944). The present study was undertaken to determine whether or not fumigation with this mixture would reduce the germinability of seeds intended for planting.

The acrylonitrile-carbon tetrachloride mixture is a clear, colorless liquid with a boiling point of 69° C. The product evaporates readily when not confined. The vapors of this fumigant are 3.2 times as heavy as air and are toxic to insects, and to warm-blooded animals only at relatively high concentrations or after prolonged exposure. For this reason it is possible for workmen to handle small amounts of the fumigant without special training or equipment.

The fumigant is normally effective against stored products insects at dosages of 2 to 3 pounds per 1000 cubic feet within a 24- or 48-hour exposure period.

As it might be used to fumigate seeds in many types of storage, warehouses, laboratories, granaries, drawers, metal containers, etc., the dosages of the acrylonitrile-carbon tetrachloride mixture might not be measured accurately in many instances. In fumigating seeds in small containers the tendency would be to apply overdoses; therefore, this study has included the possible effects of excessive dosages and repeated applications of the fumigant upon the germinability of seeds and the vigor of seedlings.

[1] Journal Paper No. 798, New York State Agricultural Experiment Station, Geneva, N. Y.

[2] Associate Professors of Entomology and Seed Technology, respectively.

[3] "*Carbacryl*," manufactured by American Cyanamid Company.

MATERIALS AND METHODS.—Popular varieties of common field and vegetable seeds were purchased from open stocks. No special effort was made to secure dry seeds, but the moisture contents as determined at the initiation of the germination tests were never above optimum percentages for storage. The varieties listed in table 1 were at the time of fumigation represented by year-old seed, those in tables 2 and 3 by seed about 8 months old, and those in table 4 by recently harvested seedstocks.

Each seed lot was divided into 2, 3, or 4 portions. One of these was retained as a check. The other portions were placed in cloth or unsealed paper containers preparatory to fumigation. These were arranged loosely in small metal drums and if necessary bulk seed was added to fill uniformly three-fourths the space. The fumigant was pipetted onto paper toweling placed just above the seeds and the drums were sealed immediately. The rates of applications were 1, 2, 3, 5, or 25 pounds per 1000 cubic feet and the exposure periods were 24 or 48 hours.

The containers of fumigated seeds were lifted from the drums, placed in cardboard shipping boxes, and held for periods of 1 week, 7 months, or 10 months before being opened. All seeds were germinated in the official seed testing laboratory of the New York State Agricultural Experiment Station at Geneva, N. Y., and in accordance with rules for testing seeds of the Association of Official Seed Analysts (1947). All 100-seed test lots (quadruplicates of 1, 2, or 3 treatments and checks), representing a specific seed stock, were placed upon 2 germinator trays in order that temperature and moisture conditions would be uniform.

Seed representing certain varieties was sown in clean sand, contaminated soil, or both, in a cool greenhouse. At least two 100-seed replicates were planted without chemical protection while others were dusted with a fungicide, either tetramethyl thiuram disulfide,[1] tetrachloro benzoquinone,[2] or 2, 3 dichloro-1, 4 naphthoquinone.[3]

RESULTS.—*Experiment 1.* In May, 1946 2 kinds of field seeds and 11 kinds of vegetable seeds were fumigated and placed to germinate after natural aeration for 1 week. As shown in table 1, the moisture percentages indicated thoroughly dried and cured seed. The dosages of 1 and 5 pounds of the fumigant per 1000 cubic feet of space with 24-hour exposures were arbitrarily selected since good insect kills had been effected within these ranges.

At the end of the official germination period all test lots of each kind of seed were visibly uniform. A panel of analysts appraising the test on the basis of number, uniformity, and vitality of germinants and of the presence of mold fungi did not distinguish between the fumigated and non-fumigated seeds. The average difference in germination between the fumigated and non-fumigated seeds of any variety never exceeded 6 per cent, which is within the limit of natural variation or the tolerance established by the Association of Official Seed Analysts. Actually, the former excelled the latter in number of times highest germination and in average germination of all varieties, although not significantly.

Experiment 2. In January, 1948, a series of 21 varieties (13 kinds) of seeds was fumigated at the rate of 2 pounds of the acrylonitrile-carbon tetrachloride mixture per 1000 cubic feet for 48 hours, followed by aeration and a repeat fumigation of 3 pounds for 48 hours. All of the seed lots were treated in duplicate. One set was removed from the exposure chamber and held for 10 months in common storage at Stamford, Connecticut. The other set was shipped to Geneva, New York, and stored in a heated laboratory for 10 months.

Table 1.—The viability of acrylonitrile-carbon tetrachloride fumigated seeds as determined in paper substrates, May 1946.

SEED USED	PER CENT MOISTURE CONTENT	PER CENT GERMINATION OF SEEDS EXPOSED 24 HOURS TO DOSE OF		
		1 lb./1000 cu. ft.	5 lbs./1000 cu. ft.	Check
Black Valentine Bean	12.6	95	96	95
Detroit Dark Red Beet	9.5	74	80	80
American Drumhead Savoy Cabbage	6.5	95	96	96
Selected Danvers Carrot	7.1	89	93	92
Golden Cross Bantam Corn	10.1	90	91	90
New Davis Perfection Cucumber	7.0	93	91	92
Iceberg Lettuce	5.9	96	95	98
Welcome Oats	12.9	98	98	98
Yellow Globe Danvers Onion	7.7	91	92	89
Laxtons Progress Peas	10.0	76	80	79
Scarlet Globe Radish	5.6	93	94	94
Rutgers Tomato	8.4	90	92	91
Spring Wheat	12.0	49	47	49

[1] *Arasan*, E. I. duPont de Nemours & Co.
[2] *Spergon*, United States Rubber Co.
[3] *Phygon*, United States Rubber Co.

Test portions were withdrawn from the latter set one week after fumigation and placed to germinate in paper substrates. In November, 1948, the seeds in storage at Stamford were sent to Geneva and germination studies were initiated with both sets. These studies included seedings in greenhouse soil as well as on paper blotters or toweling in the laboratory. The results from seeds in the two storages were not significantly different. The following seeds were included in the tests:

Bean	Burpee's Green Pod
Bean	Bountiful
Bean, Lima	Fordhook 242
Beet	Extra Early Egyptian
Beet	Detroit Dark Red
Cabbage	All Seasons
Cabbage	Wakefield
Carrot	Chantenay
Carrot	Imperator
Corn	Stowell's Evergreen
Cucumber	Long Green
Lettuce	Simpson
Lettuce	Great Lakes
Onion	Ebenezer
Onion	Prizetaker
Peas	Mammoth Melting
Peas	Thomas Laxton
Pumpkin	Small Sugar
Squash	Blue Hubbard
Tomato	Rutgers
Tomato	Marglobe

Neither the percentages of germination nor the vitality of the seedlings indicated that the treatments had injured the seeds. It was shown also that no deleterious effects from fumigation developed during the 10-month-storage period. Mold fungi and certain soft-rot bacteria were about equally numerous and bothersome on the fumigated and nonfumigated seed lots in the laboratory tests.

The emergence of seedlings from soil further indicated that the fumigant reduced neither the viability nor vitality of the seeds. Both pre- and post-emergence damping-off reduced the stand of plants of a few varieties apparently irrespective of the fumigation.

Experiment 3. To determine whether or not the fumigant might affect newly harvested stocks, seeds of 13 vegetable species were fumigated at rates of 3 and 5 pounds per 1000 cubic feet for 24 hours.

Laboratory tests to determine viability were started in 1 week and 10 months subsequent to fumigation. The seedings in soil were confined to nine species and only after the 10 months' storage period. The percentages of germination after storage for 1 week are summarized in table 2. It is evident that the fumigant did not significantly reduce the germinability of any lot of seeds. Similar results from both laboratory and soil tests conducted 10 months after fumigation indicated that there was no expression of delayed injury.

Table 2.—Germination of new-crop vegetable seeds one week after fumigation with an acrylonitrile-carbon tetrachloride mixture.

Kind of Seed Used	Per Cent Moisture Content	Per Cent Germination of Seeds Fumigated at Rates of		
		3 lbs., 24 hrs.	5 lbs., 24 hrs.	Check
Bean	8.6	90	90	87
Bean, Lima	9.5	56	60	63
Beet	7.6	64	68	64
Cabbage	5.6	88	89	89
Carrot	6.8	88	83	89
Cucumber	6.0	90	93	88
Lettuce	5.2	98	98	94
Onion	7.5	98	99	98
Peas	8.6	94	96	94
Radish	5.1	90	88	96
Squash	6.3	97	96	98
Sweet corn	7.3	98	97	98
Tomato	6.0	83	82	78

Preliminary readings for beet, cabbage, carrot, cucumber, squash, and tomato after germination periods of 4, 6, 6, 4, and 6 days, respectively, showed that the fumigant did not retard the germination of these kinds of seed.

Mold fungi developed uniformly on all the tests in the laboratory, indicating that the acrylonitrile mixture was neither fungicidal nor did it render seeds more susceptible to mold infections.

Experiment 4. While dosages of the fumigant greater than 5 pounds per 1000 cubic feet were not required for complete kills of the confused flour beetle, *Tribolium confusum* Duv., the rice weevil, *Sitophilus oryza* L., and other stored product pests, in practice excessive amounts approaching 25 pounds might be placed in small storage bins or containers. To explore the possibility of injury at this concentration, seeds representing 6 varieties of vegetables were confined for 24 hours with the fumigant at rates of 5 and 25 pounds per 1000 cubic feet.

As shown in table 3, seeds placed to germinate 1 week after fumigation were found not to have been injured by either dosage. Furthermore, plants from fumigated seeds germinated in greenhouse

Table 3.—Germination of vegetable seeds in paper towels one week after fumigation with normal and excessive dosages of the 50-50 acrylonitrile-carbon tetrachloride mixture.

SEED TESTED	PER CENT GERMINATION		
	5 lbs.	25 lbs.	Check
Burpee's Green Pod Bean	77	81	88
Giant Green Pod Bean	88	88	96
Fordhook 242 Bean, Lima	85	80	72
Imperator Carrot	63	67	68
Early Scarlet Globe Radish	85	87	88
Sparkler Radish	88	89	91

sand beds showed similar results and were visibly identical to those from non-fumigated seeds. The green weights of the seedlings furnished additional evidence that fumigation did not affect the vitality of the seeds.

This entire group of seeds was also treated with the fungicide 2, 3 dichloro-1, 4 naphthoquinone and sown in heavily contaminated soil. The averaged stands did not indicate that the fumigation altered the fungicides efficiency in the control of damping-off. The green weight per plant from fumigated seeds of any species was not significantly different from that of the non-fumigated ones.

Experiment 5. Seeds of Thomas Laxton peas and Small Sugar pumpkin previously fumigated with the fumigant mixture, as explained under Experiment 2, were treated with certain fungicides prior to sowing in contaminated greenhouse soil. Small portions, about 400 seeds, of each lot were treated by agitation with a mixture containing either 3 parts of 50 per cent tetramethyl thiuram disulfide and 1 part diatomaceous earth, 3 parts 50 per cent 2, 3 dichloro-1, 4 naphthoquinone and 5 parts talc, or 9 parts tetrachloro benzoquinone and 1 part talc by weight. Portions of the non-fumigated bulks of peas and pumpkin were similarly treated with these fungicides. Plantings of 100 seeds per row replicated 4 times were made in a cool (55° to 70° F.) greenhouse range on December 22, 1948.

The seedling counts on January 10 are given in table 4. They show that every fungicide effected a significant increase in

Table 4.—Emergence from seeds of peas and pumpkin fumigated with a 50-50 acrylonitrile-carbon tetrachloride mixture, stored for 11 months and then dusted with fungicides prior to planting in contaminated greenhouse soil.

FUNGICIDE DUST	PER CENT EMERGENCE FROM			
	Peas		Pumpkin	
	Fumigated	Check	Fumigated	Check
Tetramethyl thiuram disulfide	65	63	78	73
2, 3 dichlo-o 1, 4 naphthoquinone	82	81	88	90
Tetrachloro benzoquinone	74	78	59	56
Check	33	31	22	26

stand as compared to the seeds which were not fumigated.

The fumigation did not reduce the stand nor the size of plants of either species. It is apparent also that every fungicide protected the fumigated seed fully as well as non-fumigated seed. The influence of fumigant upon seeds treated with fungicides prior to fumigation is under study and will be discussed in a later publication.

SUMMARY AND CONCLUSIONS.—Studies were made from 1946 to 1948 to determine what effect fumigation with a 50-50 mixture of acrylonitrile and carbon tetrachloride has on the germinability of seeds.

Bean, beet, cabbage, carrot, corn, cucumber, lettuce, lima bean, oat, onion, pea, pumpkin, radish, squash, tomato, and wheat seed were included in the study. Several varieties of some of these were used. Fumigations were made in the laboratory at dosages ranging from 1 to 25 pounds per 1000 cubic feet. Germinability was tested by placing the seeds on paper toweling or blotters and in greenhouse sand and soil.

There was no evidence that fumigation with the mixture had any immediate or delayed deleterious effect on any kind of seed. It had no effect upon the incidence or growth of mold fungi. Three fungicides commonly used for seed treatment protected fumigated seeds as efficiently as non-fumigated seeds in plantings in contaminated greenhouse sand and soil.

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Methyl Bromide Fumigation of Imported Orchid Plants

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Methyl bromide fumigation has been used for several years as a method of treating orchid plants imported into the United States to prevent the introduction of new plant pests. It was apparently used first in California for this purpose as early as 1938. Latta found methyl bromide effective against the leaf miner *Mordellistena cattleyana* Champ., and developed vacuum-fumigation schedules for use on dormant imported orchids. Armitage (1942) reported experience with methyl bromide for orchids. Bulger (1946) studied the tolerance of actively growing orchids in greenhouses, and developed dosage schedules for their fumigation at atmospheric pressure.

Orchid imports have expanded greatly since World War II, and their treatment has become a problem of considerable magnitude. The quality of orchid plants deteriorates, often considerably, during the period of shipment, particularly when the plants are collected from native habitats. Many factors may be responsible for any loss or decrease in quality of plants during the shipping period, but there has been a tendency for the importer to blame fumigation. The following studies were made to determine whether fumigation aggravated the deterioration caused by other factors. They were made on actual importations from South America, Europe, and India, consisting of dormant, semidormant, and actively growing plants and representing a wide range of conditions attending the shipment of orchid plants. A total of 50,249 orchid plants was involved, and individual records were kept on 3087 plants from 72 lots.

PROCEDURE.—Arrangements were made with importers close to New York to use their incoming shipments of plants in the tests. On arrival at the Plant Inspection House, Hoboken, N. J., two groups of 20 to 25 plants were segregated from an imported lot and labeled with code numbers, and a record was made of leaf drop, condition of pseudobulbs, and new growth of each plant. One group served as the check and was allowed entry after close inspection. The second group was returned to the original shipment and the whole fumigated. After fumigation, the shipment including the unfumigated checks proceeded to the importer and received normal handling.

The plants were kept under observation in the importer's greenhouse for considerable periods without the operator knowing which lot was untreated. At the beginning the labeled plants were observed after 2 weeks, 1, 2, and 4 months. In later tests the observations were spread over greater intervals, usually 1, 2, 10, 12, and 20 months. General notes were also kept on the condition of the entire shipment in addition to detailed records of the behavior of labeled plants.

Practically all plants suffered some loss of leaves during transit. When examined at Hoboken, most varieties had lost 25 to 40 per cent of their leaves, even in good-quality shipments. In poor-quality shipments the leaf loss ran as high as 60 to 100 per cent, and in addition some pseudobulbs or even complete plants were dead.

Poor-quality shipments were due to several conditions. Some plants were poor to start with (Jones 1945). The state of growth when harvested and the handling before shipment contributed materially to the condition of the plant upon arrival in the United States. Other plants were overlong in transit; one shipment was held up more than 2 months by a strike and eventually only about 5 per cent was salvaged. Some shipments were injured enroute, particularly the first air shipments packed in corrugated paper boxes, which did not adequately protect the plants from mechanical injury. When this factor was pointed out to importers they arranged for further shipments to be packed in plywood containers. In a number of air-express shipments plants near vent openings were frost-bitten. In one shipment containers were too tight, and a

[1] Acknowledgment is made to R. Latta, G. G. Becker, E. Kostal, R. B. Swain, H. Roth, and other inspectors, also of this Bureau, at the Plant Quarantine Inspection Station, Hoboken, N. J., for their suggestions and aid in making the tests; and to the various importers for their cooperation.

damping-off pathogen of the genus *Pythium*, probably *ultimum*,[1] developed and destroyed an estimated 10 per cent of the plants.

Detailed records were maintained on labeled plants as follows: 19 importations of *Cattleya mossiae*, 3 of *C. gaskelliana*, and 5 of *C. percivaliana* from Venezuela; 8 of *C. gigas*, 13 of *C. trianae*, 1 of *C. mendelli*, and 1 of *C. dowiana* from Colombia; 8 of *C. labiata*, 1 of *C. harrisoniae*, and 1 of *Oncidium varicosum* from Brazil; 2 of *Cattleya schroderae*, 2 of *C. leudemanniana*, 1 of *Lycaste skinneri*, 1 of *Odontoglossum* sp., 1 of *Oncidium splendidum*, 1 of *Schomburgkia* sp., and 1 of *Vanda* sp. from various sources; 2 of *Cattleya* hybrids, 2 of *Cymbidium* sp., 1 of *Cypripedium* sp., and 1 of *Odontioda* sp. from Europe.

Shipments of dormant *Cattleya mossiae*, *C. gigas*, *C. trianae*, *C. labiata*, *C. gaskelliana*, *C. percivaliana*, *C. harrisoniae*, and *C. mendelli*, because of leaf-mining insects were fumigated in a sustained 15-inch vacuum with a dosage of 3 pounds of methyl bromide per 1000 cubic feet for 2 hours at 70° F., or for 1.5 hours at 80°. Other shipments of dormant or semidormant *Cattleya mossiae*, *C. gigas*, *C. trianae*, *C. labiata*, *C. percivaliana*, *C. schroderae*, *C. leudemanniana*, and *C. dowiana*, *Lycaste skinneri*, *Odontoglossum* sp., *Oncidium splendidum*, *O. varicosum*, *Schomburgkia* sp., and *Vanda* sp. were fumigated at atmospheric pressure with 2 pounds of methyl bromide per 1000 cubic feet for 2 hours at 70°, with 1.75 pounds at 75°, or with 1.5 pounds at 80°. The *Cattleya* hybrid, *Cymbidium* sp., *Cypripedium* sp., and *Odontioda* sp. plants from Europe were in active growth and were also fumigated at atmospheric pressure.

High humidity was maintained in all fumigations. At the end of each fumigation the chamber was substantially evacuated and refilled with air three times to remove the fumigant.

RESULTS.—There was practically no difference in reaction of the labeled plants between untreated and fumigated lots. Obviously the loss of leaves and plants did not stop at the time the shipments were recorded as they passed through the Plant Inspection House, but continued as the plants reestablished themselves in their new environment. In most of the shipments, however, the additional leaf and plant loss was no greater in the fumigated plants than in the untreated ones, as shown in table 1, which presents the growth records for representative shipments.

The dormant *Cattleyas* fumigated with vacuum schedules showed no reduction in quality except two other poor-quality shipments of *C. gigas*, which had approximately 10 per cent greater losses in the fumigated plants. Good-quality shipments of *C. gigas* showed no effect from fumigation. There was no difference in reaction between plants shipped by air express and those shipped by water.

All the shipments fumigated at atmospheric pressure reacted normally. This group included dormant and semidormant collected plants and established cultivated plants. In every instance the fumigated plants were in as good condition as the untreated ones.

All the vacuum fumigations were necessary because the shipments were infested with the orchid fly *Eurytoma orchidearum* (Westw.), and leaf-mining insects. The efficiency of the fumigation is indicated by the fact that, although these insects were generally alive when intercepted at the Plant Inspection House, none were found alive in any of the many post-fumigation examinations made at the importer's greenhouses. Actual check of efficiency was also made on the following insects in small-scale tests: Three tests on the orchid fly and a coleopterous leaf miner, undetermined but near *Limnobaris;* and one test on *Mordellistena* sp., a leaf miner, and on a lepidopterous borer *Castnia* sp. Complete kill of all was obtained. Check tests of shipments fumigated at atmospheric pressure indicated complete control of armored scales but slight survival of soft scales. These findings corroborate the results obtained by Bulger (1946).

SUMMARY.—Observations were made on 72 importations of orchid plants from South America, Europe, and India to determine whether or not methyl bromide fumigation, required as a condition of entry into the United States, caused reduction in quality. Two lots of plants were segregated from each shipment, and individual records of leaf and pseudobulb loss and new growth were made, one lot serving as the check and the other repre-

[1] Identified by D. P. Limber of the Plant Inspection House staff.

Table 1.—Condition of orchids 8 to 12 months after fumigation with methyl bromide.[1]

Orchid		Quality of Shipment	Treatment	Per Cent Loss			Per Cent of New Growth Produced	
Variety	Source			Leaves	Pseudo-Bulbs	Plants	New Shoots	Bloom Stalks[2]
			Vacuum Fumigation					
Cattleya mossiae	Venezuela	Poor	Fumig.	80	6	0	29	0.5
			Check	73	3	0	28	0
		Good	Fumig.	25	0	0	41	7.6
			Check	20	0	0	34	4.0
gigas	Colombia	Poor	Fumig.	75	47	35	17	0.7
			Check	72	37	29	20	0
		Good	Fumig.	73	18	10	28	3.5
			Check	73	17	3	30	0.9
trianae	Colombia	Poor	Fumig.	64	26	0	52	1.1
			Check	65	26	0	44	2.4
		Good	Fumig.	53	5	0	35	10.8
			Check	62	3	0	18	5.6
labiata	Brazil	Poor	Fumig.	76	29	9	18	1.4
			Check	73	19	5	22	2.8
		Good	Fumig.	63	6	0	31	—
			Check	56	7	0	30	—
gaskelliana	Venezuela	Fair[3]	Fumig.	62	1	0	18	—
			Check	70	4	0	18	—
		Good	Fumig.	59	2	2	35	10.0
			Check	44	2	0	34	8.0
harrisoniae	Brazil	Poor	Fumig.	89	11	0	30	1.0
			Check	91	48	5	24	1.0
mendelii	Colombia	Good	Fumig.	70	24	10	51	—
			Check	72	16	4	52	—
			Fumigation at Atmospheric Pressure					
dowiana	Colombia	Good	Fumig.	93	37	25	11	—
			Check	82	33	30	16	—
Oncidium varicosum	Brazil	Poor	Fumig.	100	3	0	30	5.0
			Check	100	27	10	27	5.0

[1] Percentages of losses and production of new growth based on comparison with total number of pseudobulbs.
[2] From 1 to 3 flowers per stalk, according to the variety.
[3] Observations made after 2 months.

senting the fumigated shipment. From a total shipment of 50,249 plants 3087 were observed for periods up to 20 months after importation. These represented good- and poor-quality shipments, transported by air or water, in dormant, semidormant, and full-growth condition. Dormant plants of 8 species were fumigated in a 15-inch vacuum, and 18 species at atmospheric pressure, without any lowering of quality except in two instances, where poor-quality *Cattleya gigas* shipments were involved.

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Tests of Insecticides Against the Meadow Spittlebug on Seed Alfalfa[1]

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Tests of certain insecticides against nymphs of the meadow spittlebug, *Philaenus leucophthalmus* (L.), were made in Wisconsin in 1947 (Chamberlin *et al.* 1948). In these tests chlordan was the most effective material used. In the 1948 tests, reported in the present paper, chlordan was used as a standard treatment; DDT and benzene hexachloride, both of which showed some promise in 1947, were retested; and toxaphene and parathion were tested for the first time. This is a report of experimental results and does not constitute a recommendation of any of the materials tested. Alfalfa that has been treated with any of them should not be fed to dairy animals or to meat animals that are being finished for slaughter.

Tests in Door County.—The first tests were made in Door County, Wisconsin, on May 17. Small plots of 8-inch alfalfa were sprayed with 3-gallon pressure-type sprayers at the rate of 100 gallons per acre. There were eight treatments and a check, with four replications of each. Spittle masses were uniformly distributed over the plots on the day of treatment. Drought in May and early June retarded the growth of the alfalfa and caused many plants to dry up later, so that no reliable infestation count could be made after June 2. Infestations were measured by counting the stems bearing spittle masses in lots of 10 stems collected at random in each replicated plot. These counts, the materials used, and the dosages applied are shown in table 1.

Table 1 shows that significant control at the 5-per cent level was obtained with all materials except parathion, and that toxaphene at 1.5 pounds per acre, either as a wettable-powder spray or as an emulsion, was significantly better than the wettable-powder sprays of chlordan or DDT or the chlordan emulsion. Parathion in the quantity used appeared worthless.

Tests in Sheboygan County.—On June 10 and 11 alfalfa of good stand, 18 to 24 inches tall, in Sheboygan County, Wisconsin, was sprayed with chlordan and toxaphene as wettable-powder suspensions and emulsions. Spraying was done from a 20-foot boom, mounted in front of a panel truck, having 13 nozzles with 0.039-inch apertures. The pump was a low-pressure centrifugal-jet type driven by a gasoline engine. At a driving speed of 5 miles per hour 15 gallons of spray per acre was applied. The gauge pressure next to the

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Table 1.—Numbers of stems infested with spittle masses in lots of 10 stems in each replication in sprayed and unsprayed alfalfa. Sturgeon Bay, Wisconsin, June 2, 1948. Treated May 17.

Treatment	Dosage Pounds of Active Ingredient per Acre	Replication				Total
		I	II	III	IV	
Toxaphene:						
Emulsion	1.5	0	0	2	0	2
Wettable-powder suspension	1.5	0	0	0	3	3
DDT:						
Emulsion	1	0	1	0	5	6
Wettable-powder suspension	1	4	5	2	4	15
Benzene hexachloride wettable-powder (5% gamma) suspension	0.133	1	0	2	5	8
Chlordan:						
Emulsion	1	2	2	2	4	10
Wettable-powder suspension	1	6	0	3	5	14
Parathion wettable-powder suspension	0.25	7	10	9	7	33
Check, no treatment	—	8	7	9	8	32

Difference required for significance at 5-per cent level in totals, 9.35.

Table 2.—Numbers of stems infested with spittlebug nymphs in lots of 20 stems and of adults caught in 2 sweeps from each plot. Sheboygan County, Wisconsin, 1948. Treated June 10 and 11. Stems collected on June 17 and adults on June 29.

Insecticide and Strength in Pounds per Acre	Infested Stems Block					Adults Collected Block				
	I	II	III	IV	Mean	I	II	III	IV	Mean
Toxaphene wettable:										
Powder suspension pounds 1.5	1	1	0	2	1	5	0	0	0	1
Toxaphene emulsion pounds 3	0	2	2	0	1	0	0	0	3	1
Chlordan wettable:										
Powder suspension pounds 1	11	5	2	6	6	3	2	0	1	2
Chlordan emulsion pounds 1	11	6	15	4	9	7	8	3	3	5
South check. Not treated	15	12	15	12	14	28	21	47	23	30
North check. Not treated	16	18	18	16	17	19	17	98	56	48

pump varied between 30 and 40 pounds but usually was nearer 30 pounds per square inch.

The plots were 21 feet wide and 120 rods long. Owing to the shape and location of the plots, treatments could not be run in replicate without considerable trampling by the spray truck. Therefore, only single-treatment plots and two checks were set up.

On June 11, the day on which spraying was completed, the average infestation of stems in the checks was 85 per cent. On June 17 infestation in the various plots was determined by counting the stems bearing spittle masses in lots of 20 stems picked at random in each of four locations spaced equally the length of the plots. The materials and dosages used and the infestation counts made on this date are shown in table 2.

For convenience and to show the consistency in the counts, the four parts of the plots are set up in table 2 as blocks, each one of which contains both checks and all treatments. Obviously, however, these parts do not represent randomized treatments. The heavy application of the toxaphene emulsion (3 pounds per acre) was caused by an error in using a 50-per cent instead of a 25-per cent concentrate as was intended.

The difference between the number of infested stems in the checks and in the treatments is so great that it is doubtless significant. It is pointed out also that, when the data are analyzed as if derived from randomized treatments, a highly significant difference is shown between treatments and checks and the toxaphene preparations are significantly better than the chlordan preparations.

Sweepings were made in all plots on June 29, when most of the spittlebugs had become adults. The counts of adults in two sweeps of the net in each of the same four parts of each plot are also shown in table 2. The results appear to show a significant difference for treatments. If they are analyzed, as were the data on nymphs, a highly significant difference is shown between treatments and the checks, but there are no significant differences between treatments.

It seems worthy of note that the effect of treatments applied for control of nymphs to such long, narrow strips of alfalfa with large areas of untreated alfalfa adjoining should be so striking 18 to 19 days after the applications and after most of the adults, which are active flyers, had emerged. A reduction in the number of adults large enough to be so easily measurable some time after there had been opportunity for the adults to spread from untreated alfalfa suggests that ultimately the control of the nymphs was greater than is indicated by the counts of infested stems on June 17 or, in other words, the insecticides had shown enough residual action to continue to kill after that date. Examination of the data in table 2 illustrates this point further. On May 17 the most heavily infested check was less than twice as heavily infested as the chlordan emulsion plots, which showed the poorest control of any of the treated plots, and on June 29 there were approximately nine times as many adult spittlebugs in this same check as in the same chlordan plots. By July 15, after a large acreage of untreated alfalfa in the same field had been cut and ample opportunity afforded the adults to migrate into

the uncut treated plots, the numbers throughout the test plots were more or less equalized. On June 29 the checks were almost completely without bloom and the alfalfa was several inches shorter than in the treated plots, which were in heavy bloom. Delayed bloom appeared in the checks in mid-July. In August a much heavier seed set was apparent in the treated than in the untreated plots.

Although no exact measure of the comparative seed yields from the various plots could be made, the farm superintendent of the Sheboygan County Farm stated that a strip cut with a combine in the untreated alfalfa for the full length of the plots (120 rods) gave 6 to 8 inches of seed in an ordinary alfalfa seed sack and that a similar strip through the treated alfalfa (exact treatment not known) "practically filled" such a sack with seed. It is estimated that the treated alfalfa produced about five times as much seed as the untreated.

ADDITIONAL TESTS IN FOND DU LAC COUNTY.—Another field of first-growth alfalfa in Fond du Lac County was treated on June 11, with the same chlordan and toxaphene formulations as was the preceding field but at heavier rates of application. The alfalfa was at about the same stage of growth as that in the Sheboygan County field. The same spray boom was used, but a small gear pump powered by another engine was substituted for the centrifugal-jet unit. The sprayed plots were twice as wide as the strip covered by the spray boom, or 42 feet wide, and 30 rods long. This apparatus maintained a gauge-pressure next to the pump of 40 pounds per square inch and delivered nearer 30 than 15 gallons of liquid per acre at a driving speed of 5 miles per hour. Apparently, there was less loss of pressure between the pump and the nozzles with this pump than with the centrifugal-jet pump, presumably because the latter was unable to supply liquid up to the capacity of the nozzles. The heavier application of liquid by the gear-pump unit resulted in heavier dosages of actual insecticide per acre than was intended. These dosages were as follows: Chlordan in the emulsion and in the suspension, 2 pounds; toxaphene in the suspension, 3 pounds, in the emulsion, 6 pounds. In this case also, the heavier application of toxaphene as an emulsion than as a wettable-powder suspension was caused by the erroneous use of a 50-per cent rather than a 25-per cent concentrate.

The proportions of the stems infested in the treated and untreated plots on June 17, as shown by stem counts, were as follows: South check, 48 per cent; chlordan emulsion, none; chlordan wettable-powder suspension, 25 per cent; toxaphene emulsion, none; and north check, 50 per cent. The rather high infestation in the plot sprayed with the chlordan wettable-powder suspension is believed to have been caused by a light application to about one-half of this plot since it is known that, although the sample stems were collected at random throughout the plot, all the infested stems came from the part which received the lighter application. Although not shown in the stem counts, there was some infestation in all the plots; but in those plots in which no infestation was shown by the counts, the infestation was very low.

Sweeping on June 28 showed, in the same number of sweeps per plot, adult spittlebugs as follows: South check, 84; chlordan emulsion, 5; chlordan wettable-powder suspension, 19; toxaphene emulsion, 5; toxaphene wettable-powder suspension, 6; and north check, 127. As may be readily seen, the effect of the treatments on the nymphs was reflected in the number of adults caught for almost three weeks after treatments and probably longer. On the date of the sweeping the treated and untreated plots in this field showed essentially the same difference in the height of the stems and in the amount of bloom as did those plots in the Sheboygan County field.

DISCUSSION.—As is well known, spittle masses are very conspicuous on alfalfa and other plants, and it seems worthy of record that the effectiveness of the different insecticides in these experiments was estimated from the appearance of the plots before the infested and uninfested stems were counted. These estimates were entirely in agreement with the counts, except that in some cases the differences between treatments were more evident from these observations than from the counts. For example, in the Door County experiment analysis of variance of the counts does not show that the toxaphene materials were significantly better than

benzene hexachloride wettable-powder suspensions or than DDT and chlordan emulsions; yet inspection of the plots on the day of sampling left little doubt that real differences existed. Perhaps a larger sample than 40 stems per treatment would have shown these differences statistically.

SUMMARY AND CONCLUSIONS.—Three experiments were conducted in Wisconsin in 1948 in which various insecticides were sprayed on first-growth alfalfa for control of the meadow spittlebug, *Philaenus leucophthalmus* (L.). Hand and low-pressure power sprayers were used. DDT, chlordan, toxaphene, benzene hexachloride, and parathion were tested, the first three in both water suspensions and emulsions and the last two in suspensions only. Since all the materials used were not tested in each experiment, conclusions are drawn from the data as a whole and are as follows:

(1) Toxaphene either in emulsion or water suspension appeared to be superior to all other materials tested. Although as much as 6 pounds of this material was applied per acre, 1.5 pounds per acre appeared to be equally effective.

(2) Chlordan in emulsions and suspensions at 1 and 2 pounds per acre was not so uniformly effective as were the chlordan suspensions and dusts used in 1947.

(3) Benzene hexachloride (5 per cent gamma) suspensions at 1.5 pounds, or 0.133 pound of actual gamma, and DDT in an emulsion at 1 pound per acre showed some promise.

(4) Parathion as a water suspension at 0.25 pound per acre was ineffective.

(5) The treatments described, although applied primarily for the control of spittlebugs, were very effective also against the alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), which was very abundant in the Sheboygan County and Fond du Lac County fields. Consequently, it is believed that the heavier and earlier bloom and the better setting of seed in the treated plots were due to the control of both these insects.

(6) These experiments showed clearly that low-pressure and low-gallonage sprays can be used effectively in controlling certain pests of seed alfalfa.

Alfalfa that has been treated with any of the above-mentioned insecticides should not be fed to dairy animals or to meat animals that are being finished for slaughter.

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Control of Olive Scale in California with Parathion

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Since the olive scale, *Parlatoria oleae* (*Colvée*), was first reported near Fresno, California, in 1934, it has spread through much of the central valley and into southern California. Lack of effective natural enemies, difficulty of control, and the fact that the scale has over 200 host plants including many ornamentals, shade trees, and nearly all fruit trees except citrus, have facilitated this spread. On olive the principal damage is a spotting of the fruit, though heavy infestations may cause deformities of fruit and reduction in oil content. On deciduous fruits the olive scale has much the same effect as San Jose scale. Unlike San Jose scale, heavy infestations of olive scale are not so injurious to trees. Nevertheless, if uncontrolled, the vigor of the tree is reduced and smaller limbs are killed. Control has been by tent fumigation with HCN gas for olives and by oil sprays for olives and deciduous fruit trees. In certain cases neither of these controls is satisfactory and there is a continual search for newer, more effective, and less phytotoxic insecticides. Among the newer insecticides, parathion shows a great deal of promise for control of olive scale and is of further interest because of the peculiar response of the insect to the chemical.

METHODS.—Sprays were applied with

power driven orchard sprayers of standard manufacture at pressures of about 500 pounds. Spring dust treatments were applied using a Niagara orchard duster. A mid-summer dust trial on olives was made using a large fish-tail citrus duster which delivered a large volume of air at comparatively low velocity. In evaluating results of sprays and dusts four methods were used as follows: 1. mortality of adult females, 2. number of young scale on leaves adjacent to heavy overwintered infestations on limbs of peach trees, 3. number of scale per olive fruit, and 4. per cent of scaly olives.

WINTER SPRAYS.—Preliminary tests with parathion by the writer in the spring and summer of 1947 looked so promising that field tests were continued in the winter, starting in November 1947. On olives generally, November sprays of parathion alone or in combination with other organic insecticides gave poor results especially as regards kill of adult females. Through the remainder of the winter and into the spring of 1948, the scale showed a definite reaction to parathion. That this chemical persisted in the field was substantiated by bioassays made in March 1948. A swelling of the adult female and consequent lifting of the scale covering often resulted from parathion sprays. This condition occurred all during the winter months. In some cases some of the females turned from the normal reddish-purple color to brown and died. Others did not turn brown and apparently returned to normal size since, subsequently, great numbers of normal-size scale were observed to have coverings which were loose and only connected to the lower shell and plant surface through a very small fraction of the shell perimeter. Such scale were not normal in appearance because of lack of color in the central region of the body and sluggish response to the touch of a dissecting needle. By spring, many of these scale had fallen as evidenced by the presence of numerous exposed unoccupied ventral parts of scale shells. In April many live scale were seen to be producing considerable amounts of cottony wax which is rarely seen on untreated scale. As was previously noted by the writer (Stafford 1948) egg laying was delayed. Trees sprayed in November were examined on April 27 and only 8.9 per cent of the females were laying eggs, whereas 30 per cent were ovipositing on unsprayed trees. On May 12, over 98 per cent of live scale from untreated olive trees were laying eggs while only 5.6 per cent of 142 live females from sprayed trees were ovipositing. On June 24, the sprayed plots showed a variation of from 0 to 6 per cent in young olives infested with first brood scale while untreated trees averaged 24.2 per cent scaly fruit. By harvest time in October, however, the infestation on the olives was so great that none of the treatments was considered satisfactory. Nevertheless, all sprays resulted in a reduction in per cent scaly fruit at harvest from that of the same trees at harvest time of the previous year. The results are given in table 1.

Table 1.—Per cent scale-infested olives from trees sprayed November 11, 1947.

Treatment per 100 Gallons		Sept. 24, 1947 (pre-treatment)	Oct. 8, 1948
Pounds 15% Parathion	Other Materials		
3	None	100.0	45.0
3	Di-2-ethylhexyl phthalate, 1 qt.	90.0	28.0
3	Di-2-ethylhexyl phthalate, 1 qt; kerosene, 2 gallons	94.0	59.0
3	Methyl naphthalenes,[1] 1 qt.	94.0	42.0
3	50% chlorinated camphene in oil, 2 qts.	100.0	85.0
3	Chlordan, 1 qt.	96.0	67.0
3	Piperonyl cyclohexanone, 2 qts.	100.0	88.0
4	None	100.0	71.0
4	Di-2-ethylexyl phthalate, 1 qt.	98.0	83.0
7	None	88.0	53.0
7	Di-2-ethylexyl phthalate, 1 qt.	100.0	51.0
4	Diesel oil, 1 qt.	100.0	76.0

[1] *Velsicol AR 60.*

Table 2.—Average number of olive scale per peach leaf from leaves collected near bark carrying heavy overwintering scale infestations. Average of 20 leaves. Trees dusted with 4 per cent parathion dust at the rate of 50 pounds per acre.

Dates Dusted	All Scales Counted June 3, 1948	Only Live Scales Counted June 25, 1948	
		Younger than Second Stage	Second Stage or Older
April 30, 1948	8.6	23.9	17.4
May 13, 1948	97.4	22.7	17.9
May 20, 1948	40.6	8.3	0.7
May 26, 1948	54.2	3.0	0.0
April 30 and May 13, 1948	9.7	4.8	1.4
May 13 and May 20, 1948	10.4	1.0	0.0
Undusted—dust drift only	175.3	32.9	12.3

On peaches, January sprays of 3 and 4 pounds of 15 per cent parathion wettable powder per 100 gallons of water and combinations of these sprays with (1) 1 quart of di-2-ethylhexyl phthalate, or (2) 1 quart of di-2-ethylhexyl phthalate and two gallons of kerosene, or (3) 1 quart of dormant oil emulsion killed less than 50 per cent of overwintering female scale. The scale reacted in the same manner as parathion sprayed scale on olive trees. The resulting delay in oviposition of sprayed scale was reflected in the smaller number of first brood scale per leaf as measured in early June.

SPRING DUSTS.—A series of plots in a single row of olives bordering a vineyard was dusted on five different dates between April 30 and June 4 and were so arranged that some plots received one application, some two, and others three applications. A 4 per cent parathion dust was used at the rate of 50 to 100 pounds per acre at each application. The results were unsatisfactory—the best of the plots receiving 3 applications and having 76.5 per cent scaly fruit at harvest. Dusts applied after the start of hatching gave better control as measured by number of scale per 100 olives.

On four of the same dates that the olives trees were dusted the same dust was applied to 5-year-old July Elberta peach trees at the rate of about 50 pounds per acre. Two counts were made of the number of scale per leaf. The results are summarized in table 2. It appeared that dusts gave better control on peaches than on olives. This may be due to the fact that on peaches the eggs started hatching earlier and finished hatching in a much shorter period of time than on olives. Dust applied in late May was more effective than dust applied the last of April or in early May.

SPRING SPRAYS.—On olives pre-blossoming sprays were tried in an effort to avoid toxic residues and possible penetration of parathion into the fruit. A series of tests using parathion wettable powder were applied April 28 and repeated on May 11, 1948, just before the blossoms opened. The results of the sprays are given in table 3. Counts made June 24 represent infestation by the first brood while counts made before harvest in October represent infestation by two broods of scale. The use of di-2-ethylhexyl phthalate and perhaps the latex material (Table 3) increased the efficiency of parathion. Considering that these adjuncts may make the sprays more dangerous to the operator their value as additions to parathion sprays was doubtful. For comparison with parathion, a July spray of 2 gallons of medium grade summer oil per 100 gallons of water showed 53.1 per cent scaly fruit in October. Though the differences were not large, most of the treatments gave better results when applied May 11 rather than April 28. The spray containing 0.6 pound of actual parathion (in the form of a wettable powder) per 100 gallons of water was repeated in the same orchard on May 20, June 3, and June 24, 1948. The results are given in table 4. The scale and blossom development on the dates of spray application were as follows:

April 28—Estimated 30 per cent of females ovipositing. Blossoms not yet open.

May 11—Over 98 per cent of females

Table 3.—Per cent olives infested with olive scale.

TREATMENT PER 100 GALLONS		SPRAYED APRIL 28, 1948		SPRAYED MAY 11, 1948	
Pounds Parathion	Other Materials	Examined June 24	Examined Oct. 8	Examined June 24	Examined Oct. 8
0.60	None	2.0	28.0	0.0	46.5
0.90	None	0.0	15.5	0.0	11.0
1.20	None	0.0	19.0	0.0	9.0
0.45	Vinyl resin latex,[1] 2 qts.	2.0	25.0	0.0	18.5
0.45	Polyethylene polysulfide,[2] 1 lb.	0.0	27.0	2.0	27.5
0.45	Di-2-ethylhexyl phthalate, 1 qt.	0.0	19.5	0.0	18.5
0.45	Heavy summer oil (tank mix), 1 qt.	0.0	33.5	0.0	20.0
0.45	Di-2-ethylhexyl phthalate, 1 qt.; Kerosene, 2 gals.	2.0	29.5	0.0	29.0

[1] Geon Latex x31—B. F. Goodrich Chemical Company.
[2] P.E.P.S.—B. F. Goodrich Chemical Company.

Table 4.—Per cent scaly fruit at harvest from olive trees sprayed with 0.6 pounds of parathion as wettable powder per 100 gallons of water.

DATE SPRAYED	PER CENT SCALY OLIVES AT HARVEST
April 28, 1948	28.0
May 11, 1948	46.5
May 20, 1948	9.0
June 3, 1948	4.5
June 24, 1948	10.5

ovipositing. Blossoms not yet open.

May 20—Eggs and "crawlers" abundant. "Crawlers" not yet settled on tip growth. Estimated 40 per cent of blossoms open.

June 3—Eggs and "crawlers" abundant. No first brood scale developed as far as adult stage. Estimated 90 per cent of blossoms open.

June 24—Very few eggs. Young adult females present. Fruit about 0.25 inch in diameter.

A comparison of per cent scaly fruit at harvest (Table 4) with the state of scale development at the time of parathion spray application indicates that this chemical is effective against eggs and young scale. Presumably a warm spring which would shorten the oviposition and hatching period would favor control with parathion when applied just before the first hatched scale reached the adult stage. Most of the fruit would be extremely small at this time.

A spring spray on July Elberta peaches was applied when the fruit had reached about 0.75 inch in diameter. The spray of 4 pounds of 15 per cent parathion wettable powder per 100 gallons of water was applied April 28, 1948, and was followed the night after spraying by a 0.67 inch rain. Despite the rain and the presence of a heavy overwintered scale infestation, the control as measured by number of scale per leaf on May 26, June 25, and July 31, was good. The numbers of scale per leaf for sprayed and unsprayed trees on the above dates were 2.7 and 158.3, 1.6 and 229.4, and 1.1 and 165.1 respectively. The July 31 count was late enough in the season to take into account any delay in oviposition and subsequent "crawler" production which the spray may have caused.

SUMMER DUST.—Two applications of a 2 per cent parathion dust on the same plot each at the rate of 150 to 200 pounds per acre were made on olives, one on July 13, and the other on August 2, 1948, using a citrus duster. Counts of the various developmental stages of the olive scale on July 13, showed that only 3 per cent of the adult females were laying eggs. A small portion of the first brood females had not yet matured. At the time of the second dust application on August 2, 16.7 per cent of the adult females from untreated trees were ovipositing while none were laying eggs on the treated trees. On September 1, a count was made of the scale on 100-fruit samples. The results are given in table 5. Though the reduction of scale infestation in the dusted plot was obvious, the control was not satisfactory. The 91.5 per cent fewer young scale on the dusted fruit may be accounted for by killing of young and adult female scale, delay in oviposition caused by parathion, and sterility of females caused by lack of fertilization due to the greater susceptibility of the male scale to parathion.

The sterility of San Jose scale was noted by Newcomer & Yothers (1929), and the explanation that the phenomenon was due to the killing of the males and consequent lack of fertilized females was given by Yothers in 1940. That lack of fertilization caused unproductiveness in the olive scale was reported by Stafford in

Table 5.—Number of scale per 100 fruits from untreated olive trees and from trees dusted July 13, and again on August 2, 1948, with 2 per cent parathion dust at the rate of 150 to 200 pounds per acre at each application.

	LIVE ADULT FEMALES						
	Total Number	Per Cent Ovipositing	Number with Atypical Shells	YOUNG SCALE	MALES EMPTY	MALES ALIVE	MALES DEAD
Undusted	82	42.6	1	2705	91	28	16
Dusted	29	31.0	17	228	21	2	21

1947. Such unfertilized females with their large, atypically shaped coverings were found in the parathion-dusted plot and are recorded in table 5. These females became uniformly dark purple in contrast to the normal reddish-purple color. Regardless of how much the shell was extended beyond the normal size, the mouthparts remained fixed at the original point of insertion into the host underneath the scale exuviae.

Incidentally, the two parathion dust applications gave excellent control of black scale, *Saissetia oleae* (Bernard).

DISCUSSION.—The results of tests to control olive scale with parathion must be considered as preliminary. Recommendations cannot be made until studies of the persistence and penetration of the deposit (which are now under way) have been completed.

While, in general, the results were promising, it has been difficult to make a precise evaluation of them. In the first place, the action of parathion on the adult female scale is slow, especially in cool weather. Though it may not kill, parathion is of some value because it delays oviposition and probably reduces the number of eggs laid.

Parathion was most efficient in killing eggs and young scale. This was the case with many dosages tested while the same dosages often failed to kill the adult females. Thus a determination of the mortality of adult females, which is often used as a test of insecticidal efficiency, did not give a true picture of the effectiveness of parathion.

The use of parathion at certain times during the summer resulted in partial control by still another method. This method was to render many females sterile by killing a large proportion of the males. Those females which were not fertilized did not lay eggs.

SUMMARY.—Parathion, both as wettable sprays and dusts, was used to control the olive scale on olives and peaches in California. The effects of winter sprays were prolonged causing delayed oviposition in the spring but were not satisfactory.

Dusts applied in the spring did not effectively control olive scale on olives but were more effective on peaches where the oviposition and hatching periods were more effective on peaches where the oviposition and hatching periods were much shorter.

Of all sprays containing parathion, the spring sprays were the most successful on both olives and peaches. Parathion appeared to be particularly effective against eggs and immature scale.

Two applications of a 2 per cent parathion dust on olives on July 13, and August 2, 1948, at the rate of 150 to 200 pounds per acre reduced the number of infested fruit markedly. That the males were more susceptible to parathion than females was indicated by the presence of a large number of sterile females in the dusted plot.

Parathion cannot be recommended for control of olive scale until studies of deposit persistence and penetration into the olive fruit have been completed.

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Liquefied-Gas Aerosols for Pea Aphid Control[1]

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Liquefied-gas aerosols were first tested for control of the pea aphid, *Macrosiphum pisi* (Kltb.), in 1944 in Maryland (Ditman *et al.* 1945). Since then further tests have been conducted in Maryland (Ditman *et al.* 1946, 1947) and in Virginia (Anderson & Hofmaster 1948). Some Maryland canners employed this method commercially in 1947 and 1948. Liquefied-gas aerosols for pea aphid control have been tested in Wisconsin for 3 years (1946 to 1948) and compared each year with a DDT dust mixture.

Aerosols were dispensed by means of a specially constructed boom made of quarter-inch copper tubing fastened to a rectangular wooden frame 24 feet long by 20 inches wide and fitted with 24 two-gallon-per-hour oil-burner nozzles. One-half of the nozzles were attached to the rear of the frame, pointing forward and 45° to the right. The other half were attached to the front of the frame, pointing backward and 45° to the left and staggered so that all the vines would be hit. All the nozzles were directed downward at a 45° angle. The boom was hung underneath the duster hood and thus was enclosed, but no apron was used in applying aerosols. The aerosol machine traveled at the rate of 4.5 miles per hour. DDT aerosols were applied at the average rate of 11 pounds of mixture per acre, but the other aerosols were discharged faster (at the rate of 14 pounds per acre) because of a higher methyl chloride content.

Dusts were applied by means of a power duster, equipped with an enclosed 24-nozzle boom and 45-foot apron, traveling at the rate of 2.5 miles per hour. Application was at the rate of 35 pounds of dust per acre.

All the treatments were replicated six times in randomized blocks. The aphid infestation was determined from five sweeps of an insect net in each plot.

Experiment in 1946.—In 1946 an aerosol containing 5 per cent of DDT, 5 per cent of methylated naphthalene, 5 per cent of cyclohexanone, 35 per cent of acetone, and 50 per cent of methyl chloride (0.55 pound of DDT per acre) was compared with an impregnated dust mixture containing 2.5 per cent of DDT in carbon tetrachloride (0.87 pound of DDT per acre). There was no untreated check. Applications were made on June 6 to peas 8 inches high when the infestation averaged 60 aphids per sweep. The wind velocity averaged 7 miles per hour during the dust application and 12 miles per hour while the aerosol was being applied. The temperature was 78° F. during both treatments. Two days after application the infestation averaged 6 aphids per sweep in the dusted plots and 28 per sweep in the aerosol-treated plots. Seven days after application the infestation in the two plots averaged 9 and 38 aphids per sweep.

Experiment in 1947.—In 1947 four aerosols were tested, as follows: (1) 5 per cent of DDT, 10 per cent of a methylated naphthalene, 35 per cent of acetone, 50 per cent of methyl chloride (0.55 pounds of DDT per acre), (2) 5 per cent of a material containing 95 per cent of tetraethyl pyrophosphate, 95 per cent of methyl chloride (0.66 pound of tetraethyl pyrophosphate per acre), (3) 10 per cent of a material containing 95 per cent of tetraethyl pyrophosphate, 90 per cent of methyl chloride (1.32 pounds of tetraethyl pyrophosphate per acre), and (4) 10 per cent of a hexaethyl tetraphosphate material containing approximately 20 per cent of tetraethyl pyrophosphate, 90 per cent of methyl chloride (0.28 pound of tetraethyl pyrophosphate per acre). These aerosols were compared with a dust mixture containing 3 per cent of DDT in trichloroethylene (1.05 pounds of DDT per acre). Six untreated plots were provided as checks. Applications were made on June 27 to peas 8 inches high with an average infestation of 100 aphids per sweep. The wind velocity ranged from 5 to 9 miles per hour and the temperature from 80° to 82° F. The results are presented in table 1.

The data taken two days after treatment shows that the tetraethyl pyrophosphate aerosols and the DDT dust mixture were more effective than the DDT aerosol and significantly superior to the

[1] In cooperation with the Wisconsin Agricultural Experiment Station.

Table 1.—Aphid survival and yield of peas on plots treated with a dust or an aerosol. 1947.

Treatment	Pounds of Toxicant Per Acre	Number of Aphids per Sweep Surviving on Indicated Days After Application		Reduction in Infestation After 2 Days	Yield of Shelled Peas (Pounds Per Acre)	Increase in Yield Over Check
		2 Days	4 Days			
Dust, DDT 3%	1.05	7	4	97%	3440	18%
Aerosols:						
DDT 5%	0.55	16	9	94	3401	16
Tetraethyl pyrophosphate 5%	0.66	6	4	98	—	—
10%	1.32	3	2	99	3482	19
Hexaethyl tetraphosphate 10%	0.28	32	23	87	—	—
Untreated check	—	249	[1]	—	2926	—
Difference required for significance at odds of 19:1	—	16.3[2]	0			

[1] Check dusted to save peas.

[2] Check not used in making the analyses.

hexaethyl tetraphosphate aerosol, which provided only fair control. The yields taken for three of the treatments were all appreciably above the yield of the check.

EXPERIMENT IN 1948.—In 1948 three aerosols were tested, as follows: (1) 5 per cent of DDT, 10 per cent of a methylated naphthalene, 35 per cent of acetone, 50 per cent of methyl chloride (0.55 pound of DDT per acre), (2) 5 per cent of a material containing 40 per cent of tetraethyl pyrophosphate, 95 per cent of methyl chloride (0.66 pound of tetraethyl pyrophosphate per acre), and (3) 2 per cent of parathion, 98 per cent of methyl chloride (0.28 pound of parathion per acre). These aerosols were compared with an impregnated dust mixture containing 1.25 per cent of DDT in a methylated naphthalene (0.44 pound of DDT per acre). Six untreated check plots were provided. Applications were made on June 13 to peas 8 inches high with an average infestation of 234 aphids per sweep. The wind velocity ranged from 7 to 10 miles per hour and the temperature was 68° F. The results are presented in table 2.

The tetraethyl pyrophosphate and parathion aerosols and the DDT dust gave excellent control and appeared equal in effectiveness. The DDT aerosol resulted in satisfactory control but was somewhat inferior to the other treatments. Yields were taken on the dust treatment and one aerosol treatment. Both were significantly superior to the yield of the check.

DISCUSSION.—The experiments of 1947 and 1948 show that when the aphid population was controlled to a high degree, dust and aerosol treatments were equally effective in increasing the yield of peas over untreated checks. Although aerosols gave good control of the pea aphid, dusts appear to be more practical and economical at the present time.

Methyl chloride, which was used as the

Table 2.—Aphid survival and yield of peas in plots treated with a dust or an aerosol. 1948.

Treatment	Pounds of Toxicant Per Acre	Aphids Per Sweep		Per Cent Reduction		Shelled Peas (Pounds Per Acre)	Per Cent Increase Over Check
		Days After Application					
		2	11	2	11		
Dust, DDT 1.25%	0.44	10	46	97	97	2164	51
Aerosols:							
DDT 5%	0.55	14	78	95	94	—	—
Tetraethyl pyrophosphate 5%	0.66	4	54	99	96	—	—
Parathion 2%	0.28	2	34	99	98	2116	48
Untreated check	—	298	1393	—	—	1433	—
Difference required for significance at odds of 19:1	—	4[1]	No difference	—	—	—	—

[1] Check not used in making the analyses.

propellent for all the aerosol mixtures, is poisonous, but with reasonable care should involve no great hazard in out-of-door application. Tetraethyl pyrophosphate and parathion are extremely poisonous. Workers applying aerosols containing these substances should wear complete gas masks approved for use with organic vapors. Until further information is available on these two materials, they should be used only on an experimental basis by experienced workers.

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Seed Treatment as a Means of Reducing Wireworm Damage to Corn

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Severe wireworm damage to corn is a common problem in Wisconsin when corn is planted on sod land or reclaimed marshland. The most severe infestations occur in peat soils which are high in organic matter and excessively moist. Direct feeding on seed and seedlings in the early part of the season reduces the stand and stunts the plants that survive.

Soil treatments with certain fumigants and other insecticidal materials have been found effective in controlling wireworms. However, these treatments usually involve considerable expense and labor and often special equipment. In the present work, the alternative of seed treatment was tried with strikingly favorable results.

In the spring of 1948 a heavy infestation of wireworms in corn was discovered in Dodge County, Wisconsin. The severely damaged area was a 6-acre section of a field which had recently been cleared of marsh grasses and willows, and was under cultivation for the first time. It was a moist peat soil with only fair drainage and subject to run-off from an adjacent hill.

The field had been planted to corn, but the stand in this area had been ruined by heavy wireworm feeding. This heavily infested part of the field had previously supported marsh grasses, while the remainder of the field had been almost completely covered with willow thickets.

Infestation, as determined by sampling with a post-hole digger of known diameter and taking a large number of samples throughout the area, proved to be approximately one million wireworms per acre, or almost 25 per square foot. A handful of soil taken anywhere in this area was almost certain to contain at least one wireworm.

The predominant species was the corn wireworm, *Melanotus communis* (Gyll.). Also present in large numbers was the wireworm *Dalopius pallidus* Brown. The wheat wireworm *Agriotes mancus* (Say) was present in smaller numbers and a few larvae of *Aeolus mellilus* (Say) were found.

MATERIALS AND METHOD OF TREATMENT.—The heavily infested section of this field was worked up for replanting in mid-June. A bushel of Pioneer 379 hybrid seed corn was divided into seven 8-pound lots and treated as follows:

No. 1—Parathion[3]	4 oz. of 50% dust per bu.
No. 2—Parathion	8 oz. " " " " " "
No. 3—Chlordan[4]	4 oz. " " " " " "
No. 4—Chlordan	8 oz. " " " " " "
No. 5—γ-Benzene hexachloride	4 oz. " " " " " "
No. 6—γ-Benzene hexachloride[5]	8 oz. " " " " " "
No. 7—Control—No insecticide	

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[2] Approved for publication by the Directors of the Wisconsin Agricultural Experiment Station and the Iowa Experiment Station, respectively.

[3] *Attaclay* impregnated with a liquid concentrate of parathion.

[4] *Riricol 50 WP*—Riverdale Chemical Company.

[5] Benzene hexachloride, 98% gamma isomer (Dow Chemica Co.) diluted with *Pyrax ABB*.

All seed had previously been treated with a fungicide at the processing plant.

In treating with insecticides, the corn was first moistened sparingly with water. The dust was then added and the seed and dust were thoroughly mixed. All seed was treated on June 18 and stored in paper bags until the time of planting. Samples of seed were taken from each lot for laboratory tests.

PROCEDURE.—Since in seed treatment, the direct effects of the insecticide on the plants may be an important factor, an attempt was made to study them as well as their effects on the insects and insect damage.

Standard germination tests were made, using petri dishes containing moist filter paper as germinators and reading after 10 days.

In order to determine the toxicity of the treated seed corn to wireworms, samples of seed from each treatment were placed in individual 2-ounce salve boxes, each containing moist peat soil and a single wireworm. There were two replicates of each sample tested. Readings were made after 10 days and the results are given in table 1.

In the field test, the corn was planted by machine (hill dropped) on June 23. The seven lots of seed were planted consecutively from one side of the infested area to the other in unreplicated plots. Each plot consisted of 16 rows of corn, approximately 650 feet long. The infestation was heaviest in the center of the experimental area and lighter at the edges. Therefore treatment number 1 (parathion 4 oz. per bu.) and the control plot were subject to damage by a lower wireworm population than were the other plots, a fact to be kept in mind in examining the data to be presented.

Wireworm population levels would have been a desirable criterion for evaluating the effects of seed treatment. However, due to the large number of samples required to obtain accurate population data and in order to use to best advantage the time and labor available, it was decided in this preliminary work, to use the stand of corn in each plot as a basis of comparison. In order to ascertain what biotic factors were involved in determining the condition of the stand, frequent spot checks were made in each plot throughout the summer to determine the abundance, activity, and mortality of the wireworms, and the presence or absence of other insects and disease.

Stand counts were made by tabulating the number of hills injured and "out" or destroyed in four rows running down the center of each plot. The height of the same number of representative plants from each plot was measured on August 4. On September 17, just before the corn was cut for ensiling, yield samples were taken in each plot. Since the ears were quite immature, yield was determined on the basis of green plant material produced per unit area. One sample from an area including 49 hills (7 hills×7 hills) and two samples from areas including 16 hills (4 hills×4 hills) were taken from the same relative positions in each plot. All samples were cut by hand and weighed in the field immediately after cutting. These data are given in table 2.

RESULTS.—No insects other than wireworms were present in sufficient numbers to have any noticeable effect on the stand and disease was not a problem. Therefore differences were attributed to the insecticidal materials present.

EFFECTS ON THE SEEDLINGS.—In germination tests all samples gave 100 per

Table 1.—Toxicity of treated seed corn to wireworms kept in close proximity to the seed in moist peat soil for a period of 10 days.

TREATMENT		SPECIES	RESULTS
Parathion	4 oz. per bu.	*D. pallidus, A. mancus*	Both dead
Parathion	8 oz. per bu.	*D. pallidus*	Both dead
Chlordan	4 oz. per bu.	*A. mancus*	Both alive
Chlordan	8 oz. per bu.	*M. communis*	Both alive
γ-Benzene hexachloride	4 oz. per bu.	*A. mancus, D. pallidus*	First dead, 2nd dying
γ-Benzene hexachloride	8 oz. per bu.	*A. mancus, M. communis*	First alive, 2nd dead
"Untreated" control		*M. communis*	Both alive

Table 2.—Results of field tests with seed treatments for protection against wireworms in replanted dent corn.

TREATMENT		JULY 21			AUGUST 4				SEPT. 17
		Per Cent			Per Cent				
No.	Material and Rate	Out	Injured	Un-injured	Out	Injured	Un-injured	Av. Height (inches)	Yield[1] Lbs./81 Hills
1	Parathion 4 oz. per bu.	24.1	3.8	72.1	28.2	6.5	65.3	40	416
2	Parathion 8 oz. per bu.	28.8	5.9	65.3	32.4	10.0	57.6	42	299
3	Chlordan 4 oz. per bu.	70.6	18.2	11.2	74.7	12.4	12.9	32	120
4	Chlordan 8 oz. per bu.	60.0	14.7	25.3	55.3	12.9	31.8	33	268
5	γ-Benzene hexachloride 4 oz. per bu.	25.3	15.9	58.8	30.0	11.2	58.8	39.5	469
6	γ-Benzene hexachloride 8 oz. per bu.	14.7	7.8	77.5	20.0	11.8	68.2	38	329
7	"Untreated" control	26.8	15.5	57.7	36.5	17.1	46.4	32	144

[1] These figures are for freshly-cut green plant material.

cent germination.

Seed treated with parathion showed earlier germination than did seed treated with the other materials or untreated seed in both laboratory and field tests. No evidence of injury to the seed or seedlings was noted. In the field, growth as well as germination appeared to be accelerated by the parathion.

In the germination test of seed treated with the 4-ounce level of γ-Benzene hexachloride seedlings displayed root deformity. Where the 8-ounce level of γ-Benzene hexachloride was used, the root deformity was more pronounced and some necrotic tissue was observed at the root tips. Root deformity caused by benzene hexachloride manifests itself in a tendency to produce short, thick, bulbous roots, and a conspicuous absence of secondary roots. No such injury to roots was observed in the field test.

Chlordan showed no detrimental or beneficial effects on seed or seedling in the laboratory. Due to the heavy wire worm damage, it was difficult to determine the direct effects, if any, on the plants in the field.

EFFECTS ON THE WIREWORMS.—Both laboratory and field tests showed parathion applied to the seed to be highly toxic to wireworms. Many dead larvae were found in the field plots. In one hill, for example, 28 dead larvae representing three species were recovered. Plants injured or killed by wireworms in the field were generally scattered in both heavily and lightly infested portions of the plots.

γ-Benzene hexachloride gave some protection against wireworms in the field. However, it was noted that injury to plants occurred where the infestation was heaviest, while in the more lightly infested portions of the plots no injured plants whatsoever were found. It is quite possible that this material has some repellent action, causing the larvae in the more lightly infested areas to feed on weeds. Where heavier infestations prevailed and the food supply was less plentiful, hunger probably overrode the repellent action and some larvae were killed. This hypothesis is supported by the fact that relatively few dead larvae were found in the γ-Benzene hexachloride plots and these were in the more heavily infested parts of the plots. In the laboratory, γ-Benzene hexachloride applied to the seed appeared to be quite toxic to the wireworms.

Chlordan proved ineffective as a protective seed treatment against wireworms in both laboratory and field tests. Both field plots were severely injured.

It should be emphasized that this work was preliminary in nature and was conducted on a relatively late second planting, after the peak of wireworm activity had passed. More significant, but perhaps less encouraging, results might be expected from an earlier planting, under otherwise similar conditions.

Further Investigation of Control of Tomato Insects in Northern California

A. E. Michelbacher, W. W. Middlekauff, Frank C. Lamb and N. B. Akesson

With the advent of the newer organic insecticides, the whole problem of tomato insect control has been reopened. For a long period there existed a need for a more effective and less hazardous insecticide to replace calcium arsenate, the material most used in northern California. Although this insecticide gave reasonably good control of caterpillars attacking tomatoes, its drift to adjacent fields has resulted in the poisoning of bees, live stock, and injury to crops susceptible to arsenical burn.

In 1946 extensive investigations were undertaken to develop methods of application that would reduce the drift hazard as well as test the effectiveness of some of the newer organic materials. The results obtained in 1946 were reported by Michelbacher *et al.* (1947). No highly satisfactory method of reducing dust drift was developed, but it was found that DDT and dichlorodiphenyl dichloroethane showed considerable promise in controlling the important caterpillars attacking tomato. The investigations were greatly expanded in 1947, and these have been published by Michelbacher *et al.* (1948). It was found that the drift hazard could be greatly reduced if insecticides were applied as concentrated sprays instead of dusts. Further, DDT and dichlorodiphenyl dichloroethane at the rate of 24 ounces of actual material per acre gave exceptionally good control of caterpillars for a period of 4 weeks or longer. These materials were much more effective than calcium arsenate, with the exception that the latter was more effective against the tomato hornworm, *Protoparce sexta* (Johan.) than was DDT when applied as a dust. Extensive residue studies were conducted which indicated that DDT and dichlorodiphenyl dichloroethane used at the rates recommended do not seem to present a serious residue hazard, at least as far as canning tomatoes are concerned. Experiments with a 10 per cent toxaphene dust were undertaken and it was found that this material was about as effective in controlling caterpillars attacking tomato as was calcium arsenate.

Despite the fact that no serious limitations or objections to the use of DDT or dichlorodiphenyl dichloroethane could be detected, it was felt that these materials warranted further investigations. This was due largely to the fact that they had not as yet withstood the test of time. Further, there was need for additional residue studies, because certain canners were still somewhat reluctant to allow their growers to use these insecticides without additional substantiation that there would be no serious residue hazard. It was also felt desirable to conduct further investigations with several of the newer insecticides.

1948 Investigations.—*Insecticides tested:* The materials used were (1) calcium arsenate, a commercial grade preparation which contained 70 per cent calcium arsenate; (2) DDT, dichloro-diphenyl-trichloroethane, which was used as a 5 per cent dust and as a 20 per cent emulsion; (3) Dichloro-diphenyl-dichloroethane, which was used as a 5 per cent dust and a 50 per cent wettable powder in a concentrated spray; (4) Methoxychlor, dianisyl trichloro-ethane, which was used as a 5 per cent dust and a 50 per cent wettable powder in a concentrated spray; (5) Toxaphene, a chlorinated camphene having the approximate empirical formula $C_{10}H_{10}Cl_8$. The technical grade used contained 67 to 69 per cent chlorine. This was used as a 10 per cent dust and as a 40 per cent wettable powder in a concentrated spray. This insecticide was also used as a 5 per cent dust in combination with 3 per cent DDT. The above insecticides were used in combination with sulfur for the control of the tomato mite. Dusting sulfur was combined with the dusts and wettable sulfur was used with the concentrated sprays.

Experimental Procedure.—Two types of plot arrangement were used in testing the above insecticides. In one, applications were made on small plots that were 10 rows wide and 53 feet long. Each treatment was replicated four times in a randomized experiment. All applications were made by hand. The dusts

were applied with rotary dusters and the concentrated sprays with knapsack sprayers. In the other experiment, treatments were applied with power equipment on a commercial experimental scale. The plots ranged from about 2 to 8 acres in size with the exception of the checks which were approximately 0.2 acres in extent. The treatments were not replicated except in the case of the checks and some of those that were applied with a ground power duster. These were run in duplicate in a randomized arrangement. Applications were made with a standard five row tomato duster equipped with three nozzles to a row, a regularly equipped airplane duster with gravity-flow hopper, and a Stearman biplane equipped with wing-length boom applicators was used to apply the concentrated sprays. A special machine was used to apply the first spray in the case of one treatment, and a converted high pressure orchard sprayer equipped to treat five rows at a time was used for the first application in the case of another.

Airplane applications were restricted to the 8 acre plots.

Trends of infestation in the experimental fields were determined by following the infestation in the developing green fruit as well as that occurring in the ripe fruit. In conducting surveys the fruits were picked and carefully examined. During harvest the degree of infestation was determined for each picking. From 200 to 800 fruits were examined depending upon the size of the plot. Infested fruit was divided into two categories: severe and superficial. The severe category comprised those fruits that had been severely injured or were infested with a caterpillar, while the superficial included those fruits which showed only a slight amount of injury.

RESULTS.—Including the check there were 10 treatments in the small plot replicated experiment which was located at Patterson, Stanislaus County, on the northwest side of the San Joaquin Valley. The information concerning treatments, rate and time of applications, and the control obtained of all species of caterpillars infesting tomatoes is given in table 1. All the treatments gave fair to good control. The 20 per cent DDT emulsion gave the best results. Good control was obtained with the 5 per cent DDT and dichlorodiphenyl dichloroethane and the 10 per cent toxaphene dust treatments. The 40 per cent toxaphene wettable powder and the 50 per cent dianisyl-trichloroethane wettable powder treatments also fell into this grouping. Poorest control was obtained with the 5 per cent dianisyl-trichloroethane dust and with calcium arsenate.

Including the check, there were 12 treatments in the experimental commercial series which was located at Davis, Yolo County, in the lower Sacramento Valley. The treatments, method of application, rate and time of applications, and the control obtained of caterpillars attacking tomatoes are given in table 2. In this series of experiments calcium arsenate gave the poorest control, and was followed by dianisyl-trichloroethane treatments. The other treatments resulted in good control, although on the average the degree of control was in favor of the treatments that contained DDT or dichlorodiphenyl dichloroethane. The differences involved, however, are probably too small to be significant.

The method of application appeared to have had some influence on effectiveness. In general the applications of dust by the ground machine were more effective than where applied by air. Further, the liquid applications by air appeared to have had an advantage over the dust treatments applied in the same manner. Here again, however, the differences are small and it would be hazardous to state that they are significant.

A heavy infestation of hornworms developed in the field at Patterson where the small plot replicated experiment was located. The important species was the tomato hornworm, *Protoparce sexta* (Johan.) although the tobacco hornworm, *P. quinquemaculata* (Haw.), was present. The effectiveness of the several treatments in controlling these pests is given in table 3. All the treatments resulted in fair to excellent control. The poorest treatment was the 5 per cent DDT dust. Where this insecticide was applied, 7.5 per cent of the plants were injured as compared to 47.4 per cent in the check. This substantiates the work of previous years which has shown that a 5 per cent DDT dust is not as effective as DDT sprays, dichlorodiphenyl dichloroethane dusts or sprays, or as calcium arsenate in controlling the tomato hornworm. A DDT dust is not effective in killing the

Table 1.—Treatment, rate of application, and per cent of infested tomatoes in the small plot replicated experiment at Patterson.

Treatment	Rate per Acre in Pounds			Per Cent of Infested Tomatoes								
				September 6 First Picking			September 23 Second Picking			October 14 Third Picking		
	July 13 First Application	Aug. 12 Second Application	Sept. 21 Third Application	Severe	Superficial	Total	Severe	Superficial	Total	Severe	Superficial	Total
Check[1]	—	—	—	1.00	1.00	2.00	11.12	1.62	12.74	5.63	1.50	7.13
Calcium arsenate dust[2]	34.0	30.0	28.0	0.50	0.00	0.50	1.37	0.12	1.50	0.12	0.25	0.37
5% DDT, 50% sulfur dust	40.0	41.0	40.0	0.50	0.00	0.50	0.25	0.25	0.50	0.25	0.00	0.25
20% DDT emulsion[3]	1.7[4]	1.7[4]	1.4[4]	0.00	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.00
5% DDD, 50% sulfur dust	31.0	30.0	31.0	0.25	0.25	0.50	0.50	0.00	0.50	0.25	0.00	0.25
5% Dianisyl trichloroethane; 50% sulfur	32.0	36.0	30.0	0.25	0.75	1.00	1.00	0.00	1.00	0.37	0.00	0.37
50% Dianisyl trichloroethane wettable powder[3]	2.9	3.4	2.9	0.75	0.25	1.00	0.12	0.00	0.12	0.12	0.12	0.25
5% Toxaphene, 3% DDT, 50% sulfur dust	29.0	30.0	27.0	0.00	0.75	0.75	0.25	0.25	0.50	0.50	0.00	0.50
10% Toxaphene, 40% sulfur dust	38.0	40.0	35.0	0.00	0.50	0.50	0.12	0.00	0.12	0.00	0.00	0.00
40% Toxaphene wettable powder[3]	8.0	9.0	8.7	0.00	0.25	0.25	0.12	0.00	0.12	0.25	0.12	0.37

[1] On July 13 check plots treated with dusting sulfur at the rate of 27.0 pounds per acre.
[2] Application on July 13 contained 46.6 per cent sulfur, that on August 12, 24.3 per cent sulfur.
[3] Applied as a concentrated spray, 15 pounds of wettable sulfur per acre applied with the July 13 treatment.
[4] Expressed as the actual amount of DDT applied per acre.

larger, more mature worms. Although the injury done was not severe, sufficient feeding occurred so that some of the fruits were injured. If it had not been for fruits damaged by hornworms in the DDT treatments, both at Patterson and Davis, the amount of infested fruit in the harvested crop would have been less than that shown in tables 1 and 2. For caterpillars other than the tomato hornworm, DDT is probably the most effective insecticide.

Neither at Patterson nor at Davis was a severe infestation in tomato fruit encountered in the check plots. In both localities and particularly at Patterson a considerable number of the injured fruits had been attacked by hornworms. The yellow-striped armyworm, *Prodenia praefica* Grote, accounted for much of the remaining injury, while some was caused by the corn earworm, *Heliothis armigera* (Hbn.) and the beet armyworm, *Laphygma exigua* (Hbn.) was responsible for a small amount. The salt marsh caterpillar, *Estigmene acraea* (Drury), which is usually

Table 2.—Treatment, method of application and per cent of infested tomatoes in experimental blocks at Davis.

Treatment and Method of Application	Approximate Pounds per Acre and Date of Application			Per Cent of Infested Tomatoes								
				October 5 First Picking			October 21 Second Picking			November 4 Third Picking		
	First July 14–15	Second Aug. 20–26	Third Oct. 5–7	Severe	Superficial	Total	Severe	Superficial	Total	Severe	Superficial	Total
Check[1]	—	—	—	6.50	1.00	7.50	5.65	0.58	6.23	4.37	1.50	5.87
Dust by ground rig:												
5% DDT, 50% sulfur	21.0	27.0	38.0	1.00	0.28	1.28	0.33	0.00	0.33	0.33	0.17	0.50
5% DDD, 50% sulfur	25.0	30.0	29.0	0.00	0.00	0.00	0.17	0.33	0.50	0.33	0.33	0.66
5% Toxaphene, 3% DDT, 50% sulfur	16.0	35.0	30.0	0.37	0.25	0.62	0.50	0.12	0.62	0.12	0.12	0.24
10% Toxaphene, 40% sulfur	21.0	38.0	34.0	1.50	0.37	1.87	1.37	0.00	1.37	0.50	0.00	0.50
5% Dianisyl-tricyloroethane, 50% sulfur	14.0	36.0	25.0	1.50	1.00	2.50	1.50	0.88	2.38	1.88	0.38	2.26
Commercial calcium arsenate[2]	21.0	26.0	27.0	2.80	1.16	3.96	3.16	1.50	4.66	2.00	1.17	3.17
Dusted by airplane:												
5% DDT, 50% sulfur	27.0	30.0	25.0	0.12	0.00	0.12	0.12	0.12	0.24	0.00	0.12	0.12
5% DDD, 50% sulfur	25.0	30.0	25.0	0.75	0.25	1.00	0.75	0.25	1.00	1.00	0.50	1.50
5% Toxaphene, 3% DDT, 50% sulfur	24.0	30.0	25.0	0.37	0.00	0.37	0.50	0.38	0.87	0.25	0.12	0.37
Liquid application by airplane[3]												
50% DDD wettable powder	4.9[4]	2.4	3.0	0.00	0.37	0.37	0.37	0.37	0.74	0.12	0.00	0.12
50% dianisyl-trichloroethane wettable powder	3.9[5]	3.0	3.0	1.37	0.37	1.75	1.50	0.25	1.75	0.50	0.25	0.75

[1] July 14 treated with dusting sulfur at rate of 34.5 pounds per acre.
[2] Dust applied July 14 contained 46.6% sulfur, that of August 20, 23.4% sulfur.
[3] Applied as concentrated spray at rate of 3 pounds to 10 gallons of water, 15 pounds wettable sulfur added to mixture applied July 14.
[4] Applied with a converted high pressure orchard sprayer fitted with booms to cover 5 rows.
[5] Applied by Naconizer.

not a pest of tomato, caused minor damage in the plots at Davis, and the tomato pinworm, *Keiferia lycopersicella* (Busck), was present in small numbers in the check plots at Patterson. The low degree of infestation in the check plots might, in part, be interpreted as reflecting a less than normal seasonal abundance of caterpillars which are usually destructive to tomato. This, however, is probably not the full explanation, for some of the important insects other than hornworms were present on other crops in nearly normal numbers. The corn earworm was found in fair abundance on baby lima beans and the yellow-striped armyworm was present in about normal numbers on alfalfa and baby lima beans. It is possible that the general application of effective treatments throughout the tomato producing regions, coupled with the small size of the check plots could account to some extent for the lack of a serious infestation in the check plots. The population in the checks would suffer a certain dilution by having insects fly out without a compensating influx.

General Observations: The 1948 season marked the end of the second year in which DDT and dichlorodiphenyl dichloroethane insecticides were used extensively for the control of insects attacking tomato. In 1948 nearly all the acreage was treated with one or the other of these materials. Whether or not this widespread use of these new insecticides exerted an influence upon normally unimportant pests of tomatoes is not definitely known. However, there was an increase in certain pests. The most noticeable was that of a leafminer, *Liriomyza* sp. By the end of the season this insect was abundant in most fields, and caused considerable defoliation. On the whole, this occurred so late that little damage was done. It is possible that some good resulted as it opened up the vines and allowed the fruit to ripen. Further, it encouraged a drier environment, which had a tendency to reduce the amount of mold. However, in at least two fields defoliation occurred so early in the season that there was a serious loss of fruit due to sunburn.

The salt marsh caterpillar was also present in more than usual numbers, and caused minor damage by feeding on the surface of ripe fruits. A spider mite, probably the Pacific mite, *Tetranychus pacificus* McG. appeared in abundance in several fields and did some damage.

In some fields treated with dichlorodiphenyl dichloroethane there appeared to be more than the usual number of tobacco flea beetles, *Epitrix parvula* (F.).

The above pests bear watching and although they have not as yet presented serious problems, they will be carefully followed. If they should increase in importance an effort will be made to determine whether or not the new insecticides are in any way responsible for the situation, and methods to correct the trouble will be investigated.

The addition of sulfur to the insecticides

Table 3.—Comparative effectiveness of several treatments in controlling hornworms in small plot replicated experiment at Patterson.

Treatment	Rate Per Acre in Pounds			Per Cent of Tomato Plants Injured
	July 13 First Application	August 12 Second Application	September 21 Third Application	September 20
Check[1]	—	—	—	47.4
Calcium arsenate dust[2]	34.0	30.0	28.0	0.0
5% DDT, 50% sulfur	40.0	41.0	40.0	7.5
20% DDT emulsion[3]	1.7[4]	1.7[4]	1.4[4]	0.3
5% DDD, 50% sulfur dust	31.0	30.0	31.0	0.3
5% dianisyl trichloroethane, 50% sulfur	32.5	36.0	30.0	1.0
50% dianisyl trichloroethane wettable powder[3]	2.9	3.4	2.9	0.82
5% Toxaphene, 3% DDT, 50% sulfur dust	29.0	30.0	27.0	0.65
10% Toxaphene, 40% sulfur dust	38.0	40.0	37.0	0.82
40% Toxaphene wettable powder[3]	8.0	9.0	8.7	0.49

[1] July 13 plots treated with dusting sulfur at rate of 27.0 pounds per acre.
[2] Application on July 13 contained 46.6 per cent sulfur, that on August 12, 24.3 per cent sulfur.
[3] Applied as a concentrated spray, 15 pounds of wettable sulfur per acre applied with the July 13 treatment.
[4] Expressed as actual amount of DDT applied per acre.

used in the experimental plots resulted in excellent control of the tomato mite, *Phyllocoptes destructor* Keifer. In none of the experimental fields was the pest even encountered. This was general throughout the tomato producing area where sulfur was used in conjunction with the insecticides applied for the control of caterpillars. However, there were fields where the tomato mite was destructive. These occurred even where sulfur had been used. No opportunity was afforded to thoroughly investigate the conditions under which these infestations developed. Based upon reports it would appear that the principal reasons for failure were due to one or more of the following reasons: (1) applications timed too late; (2) poor applications and coverage; (3) insufficient sulfur in the insecticide; and (4) insufficient material applied per acre. Besides the above reasons there is a slight possibility that in certain localities the mite may be developing a resistance to sulfur.

RESIDUE STUDIES.—Information on DDT, dichlorodiphenyl dichloroethane and calcium arsenate residue studies conducted in 1947 is reported by Michelbacher *et al.* (1947). The tomatoes used in these studies were obtained from experimental plots and were washed in the laboratory by a standardized procedure, considered comparable to a cannery wash. In the present study tomatoes for residue studies from the small replicated plot experiments were handled in the same manner. However, those obtained from commercial experimental treatments were put through a commercial washer at a large tomato cannery.

Table 4.—Residues of DDT, dichlorodiphenyl dichloroethene, dianisyl-trichloroethane, toxaphene and arsenic (As_2O_3) on tomatoes following various treatments.

Treatment and Locality	1st Application		2nd Application		3rd Application		Method of Application
	Date	Approx. Lbs. per Acre	Date	Approx. Lbs. per Acre	Date	Approx. Lbs. per Acre	
Experimental Commercial Blocks—Davis	*July*		*Aug.*		*Oct.*		
Check	—	—	—	—	—	—	—
5% DDT, 50% Sulfur	15	21.0	26	27.0	7	38.0	Ground duster
5% DDT, 50% Sulfur	15	27.0	20	30.0	7	25.0	Airplane
5% Dichlorodiphenyl dichloroethane 50% Sulfur	15	25.0	26	30.0	7	29.0	Ground duster
5% Dichlorodiphenyl dichloroethane 50% Sulfur	14	25.0	20	30.0	7	25.0	Airplane
5% Toxaphene, 3% DDT, 50% Sulfur	14	16.0	26	35.0	7	30.0	Ground duster
5% Toxaphene, 3% DDT, 50% Sulfur	14	24.0	20	30.0	7	25.0	Airplane
10% Toxaphene, 40% Sulfur	14	21.0	26	38.0	7	34.0	Ground duster
5% Dianisyl-Trichloroethane, 50% Sulfur	14	14.0	26	36.0	7	25.0	Ground duster
Commercial Calcium Arsenate	15	21.0	26	26.0	7	27.0	Ground duster
50% Dichlorodiphenyl dichloroethane Wettable Powder[2]	15	4.9	20	2.4	6	3.0	1st-Ground Sprayer; 2nd & 3rd-airplane
50% Dianisyl-Trichloroethane Wettable Powder[2]	14	3.9	25	3.0	6	3.0	1st Sprayer[3]; 2nd & 3rd-airplane
Small Plot Replicated Experiment—Patterson					*Sept.*		
Check	—	—	—	—	—	—	—
40% Toxaphene Wettable Powder[3]	13	8.0	12	9.0	21	8.7	Knapsack sprayer
5% Dianisyl-Trichloroethane, 50% Sulfur	13	32.0	12	36.0	21	30.0	Rotary hand duster
50% Dianisyl-Trichloroethane Wettable Powder[4]	13	2.9	12	3.4	21	2.9	Knapsack sprayer
20% DDT Emulsion[5]	13	1.7[6]	12	1.7[6]	21	1.4[6]	Knapsack sprayer

Table 4.—(Continued)

TREATMENT AND LOCALITY	DATE SAMPLE PICKED	RESIDUE EXPRESSED AS PARTS PER MILLION[1]			
		Before Washing	After Washing	Juice	Tomato Pomace
Experimental Commercial Blocks—Davis					
	Oct.				
Check	6	Trace	—	—	—
5% DDT, 50% Sulfur	7	0.1	0.1	Trace	1.7
5% DDT, 50% Sulfur	7	0.1	0.1	Trace	0.7
5% Dichlorodiphenyl dichloroethane 50% Sulfur	7	0.3	0.2	Trace	1.2
5% Dichlorodiphenyl dichloroethane 50% Sulfur	7	0.2	0.1	Trace	1.1
5% Toxaphene, 3% DDT, 50% Sulfur	7	DDT-0.2 Tox- 0.8	DDT-0.1 Tox- 0.8	—	DDT-1.7
5% Toxaphene, 3% DDT, 50% Sulfur	7	DDT-0.1 Tox- 0.2	DDT-0.1 Tox- 0.2	—	DDT-0.5
10% Toxaphene, 40% Sulfur	7	0.7	0.4	—	—
5% Dianisyl-Trichloroethane, 50% Sulfur	7	0.2	0.3	—	—
Commercial Calcium Arsenate	7	1.0	0.1	0.1	0.5
50% Dichlorodiphenyl dichloroethane Wettable Powder[2]	6	0.1	0.1	Trace	0.5
50% Diamsyl-Trichloroethane Wettable Powder[2]	6	1.0	0.8	—	—
Small Plot Replicated Experiment—Patterson					
	Sept.				
Check	21	Trace[7]	—	—	—
40% Toxaphene Wettable Powder[3]	21	4.4	1.9	0.8	15.3
5% Dianisyl-Trichloroethane, 50% Sulfur	21	0.5	0.2	—	—
50% Dianisyl-Trichloroethane Wettable Powder[4]	21	0.8	0.1	—	—
20% DDT Emulsion[5]	21	1.2	0.8	Trace	8.0

[1] Less than 0.05 ppm residue is reported as "trace."
[2] Applied as concentrated sprays at rate of 3 pounds to 10 gallons of water.
[3] Applied as concentrated spray at rate of 7.5 pounds to 12.5 gallons of water.
[4] Applied as concentrated spray at rate of 3 pounds to 12.5 gallons of water.
[5] Applied as concentrated spray at rate of 1 gallon to 15 gallons of water.
[6] Expressed as actual amount of DDT.
[7] "Trace" quantities of DDT and small amounts of organic chlorine were found in the control samples.
[8] *Naconizer.*

Experimental Procedure: With the exception of the untreated control, approximately one ton of tomatoes was picked from each of the experimental commercial blocks at Davis the same or the following day after the last treatment was applied. Approximately 500 pounds of tomatoes were picked from the check plots to serve as a control. The fruit was transported to a commercial tomato cannery where it was washed the next day. The various samples were run through the cannery washer consecutively, starting with the control. A slight interval was allowed between each sample but the wash water was not changed. The washing consisted of the following: Tomatoes were dumped at the rate of 10 boxes (500 pounds) per minute. They were run onto a belt and sprayed with cold water by means of three banks of high pressure sprays. They then fell into a tank of cold water of 500 gallon capacity, with an overflow of 5 gallons per minute. The water was agitated vigorously by means of compressed air escaping from four perforated pipes at the bottom of the tank and the tomatoes were propelled through the tank by means of a wooden paddle. The tomatoes remained in the tank for about 30

to 45 seconds and were then elevated to a sorting table by means of a chain belt and sprayed with two banks of high pressure sprays. The commercial procedure was to sort and trim the tomatoes at this stage in order to remove moldy and worm-eaten portions of the tomatoes, after which the sorted and trimmed tomatoes were given an additional spraying. The tomatoes for these studies, however, were taken from the belt before they were sorted or trimmed, and the final spray wash was omitted.

Samples of both unwashed and washed tomatoes were taken to the laboratory and samples of the raw fruit prepared for residue analysis. Additional samples of the washed tomatoes were juiced by means of a juice extractor[1] equipped with a 0.04 inch screen. The residue was reextracted by passing it a second time through the extractor.

Samples of the juice were heated to 210° F. for several minutes, filled into No. 2 cans and closed immediately. They were held for three minutes and then cooled by immersing in a tank of cold water. Samples of the residue from juicing operations were preserved with formaldehyde and held in glass fruit jars.

Tomatoes from the small replicated plots were picked the same day the last application was applied and taken to the laboratory directly from the field and were given a standardized washing treatment, the details of which are as follows:

1. The tomatoes were immersed in a tank of clean water and agitated gently for 1 minute.
2. They were then spread out in a single layer on a screen and sprayed for 30 seconds, using the full pressure of the city water supply. The tomatoes were then turned over and sprayed for an additional 30 seconds.

These samples were then treated in the manner previously described for the tomatoes from the large commercial plots.

Methods of Analysis: The raw samples treated with DDT, DDD, toxaphene, and dianisyl-trichloroethane were extracted with chemically pure benzene (thiophene-free) according to the method described by Wichmann, *et al.* (1946). About 2000 gms. of tomatoes were extracted with 1000 ml. of benzene by rotating in a 2.5 gallon jar. The benzene extract was set aside in the refrigerator until the analyses could be completed. The samples of juice and pomace were extracted by the method described by Tressler (1947).

DDT and dichlorodiphenyl dichloroethane were determined by the Schechter-Haller method as described by Wichmann *et al.* (1946) using the acid extraction purification procedure of Schechter *et al.* (1947). Results were calculated from calibration curves prepared from chemically pure DDT (Eimer & Amend) and purified dichlorodiphenyl dichloroethane.[2]

Since no specific chemical methods were available for the determination of toxaphene and dianisyl-trichloroethane, total chlorine was determined on the benzene extracts of samples treated with these materials by the method described by Wichmann *et al.* (1946). The concentrations of toxaphene and dianisyl-trichloroethane were calculated from the theoretical chlorine contents of these materials which are 68 per cent and 30.8 per cent respectively. It was not possible to determine the concentrations of these substances in most of the samples of juice and residue, because of the extremely small amount of chlorine involved and the presence of interfering chlorine-containing compounds. The chlorine content of the samples of juice and residue from the tomatoes treated with 40 per cent toxaphene wettable powder appeared to be high enough to justify calculation of the residue in terms of toxaphene.

Arsenic was determined by the method of Cassil & Wichmann (1939) on canned samples of juice and preserved samples of residue both from the washed and the unwashed samples. The arsenic content of the original tomatoes was calculated using the ratios of juice to pomace obtained on each lot.

Results: The results obtained along with a summary of the information concerning the treatments are given in table 4. In general, the results are similar to those obtained in 1947, but the residues of DDT and dichlorodiphenyl dichloroethane on the commercial samples tended to be a little lower than those found in 1947. Toxaphene residues, particularly in the samples treated with 40 per cent wettable powder applied as a spray, were somewhat higher than residues of the other insecticides. The residues of DDT and

[1] Chisholm-Ryder Model F.
[2] Furnished by Rohm and Haas Company.

DDD were extremely low in all of the washed samples and in all of the juice samples that were tested, and it probably may be assumed that the residues of toxaphene and dianisyl-trichloroethane would also be low.

In substantiation of the results obtained in 1947 the data show a marked concentration of DDT and dichlorodiphenyl dichloroethane in the tomato pomace. The results obtained on the samples treated with 40 per cent toxaphene wettable powder indicate that toxaphene like DDT becomes concentrated in the tomato pomace during juice extraction.

In further agreement with the results obtained in 1947, the data show that residues of calcium arsenate, although higher than DDT or dichlorodiphenyl dichloroethane, in the unwashed tomatoes are more effectively removed in the wash and after washing has approximately the same concentration as the other insecticides. Also in agreement with the 1947 results is the fact that arsenic is more evenly distributed between juice and pomace than is DDT or dichlorodiphenyl dichloroethane.

The relative effectiveness of the laboratory and the commercial washing treatment cannot be ascertained from the data. The effectiveness of removal appears to depend to a considerable extent on the amount of residue on the unwashed fruit, the wash being less effective with low concentration of residue than with high concentrations. The small amount of residue on the majority of the unwashed tomatoes makes it extremely difficult to obtain a true picture of the efficiency of either washing treatment.

SUMMARY AND CONCLUSIONS.—The effectiveness and suitability of DDT and dichlorodiphenyl dichloroethane as insecticides for the control of caterpillars attacking tomatoes have been extensively investigated for three seasons. With a single exception they have proved to be more effective than calcium arsenate. Against *Protoparce sexta*, calcium arsenate is more effective than a 5 per cent DDT dust applied at the rate of 30 pounds per acre. However, if an equivalent amount of DDT is applied as a wettable powder in a suspension spray or as an emulsion spray, satisfactory control is assured. Under northern California conditions not more than three applications of DDT or dichlorodiphenyl dichloroethane are necessary to insure excellent control. For each application 1.5 pounds of actual material should be applied per acre, which is equivalent to 30 pounds of a 5 per cent dust or 3 pounds of a 50 per cent wettable powder.

Other chlorinated hydrocarbons investigated were Methoxychlor and Toxaphene, a chlorinated camphene, the technical grade of which contained 67 to 69 per cent chlorine. This latter material applied as a 10 per cent dust at the rate of 30 pounds per acre resulted in rather satisfactory control of caterpillars attacking tomatoes. Excellent control was obtained where it was used in combination with DDT. A dust containing 5 per cent Toxaphene and 3 per cent DDT and applied at 30 pounds per acre per application warrants additional study. Methoxychlor, both as a dust and as a water suspension spray, resulted in the poorest control of any of the chlorinated hydrocarbons investigated. Its range of effectiveness paralleled rather closely that obtained with calcium arsenate.

In order to insure the control of the tomato mite, *Phyllocoptes destructor* Keifer, the above mentioned insecticides should be used in conjunction with sulfur. With dusts the sulfur content should not be less than 50 per cent. If injury by the tomato mite is not apparent by early September, the sulfur can be safely omitted from the later treatments.

The 1948 season marked the close of the second year in which DDT and dichlorodiphenyl dichloroethane insecticides were used extensively for the control of insects attacking tomato. Whether or not the widespread use of these insecticides exerted an influence upon normally unimportant pests of tomatoes is not known. However, there was a noticeable increase in the population of some of these. Most important was that of a leafminer, *Liriomyza* sp., which by the end of the season was so abundant in many fields as to cause considerable defoliation. Little damage resulted, although in at least two fields defoliation occurred so early in the season that there was serious loss of fruit due to sunburn. The salt marsh caterpillar was present in more than usual numbers, and caused some slight damage. A mite, probably the Pacific mite, *Tetranychus pacificus* McG., was encoun-

tered in abundance in several fields. The above pests bear watching and if they should develop into serious problems, every effort will be made to determine whether or not the new insecticides are in any way responsible, and means of correcting the situation developed.

The residue studies substantiate the information obtained in 1947. Under the conditions of the present experiments, with only a few exceptions, insignificant amounts of residue were present on the washed tomatoes and in the juice extracted from these tomatoes. Considerably higher concentrations of residues were present in the pomace or residue from juice extraction, particularly with the new organic insecticides. Arsenic was reduced to about the same level as the other insecticides after washing, but did not show as marked an increase in concentration in the pomace as did DDT, dichlorodiphenyl dichloroethane and toxaphene. From the information obtained, it appears that there is no serious residue hazard involved with canning tomatoes where dichlorodiphenyl dichloroethane, DDT or the DDT-Toxaphene combination are used for the control of caterpillars attacking tomato. This is particularly true if these insecticides are not used at a concentration higher than recommended in this paper. In all cases in the samples from the commercial blocks, there were 0.05 p.p.m. or less of residue in the juice and from 0.5 to 1.7 p.p.m. in the pomace. Because of the relatively higher residue in the tomato pomace, it probably should not be fed to livestock, particularly dairy cattle.[1]

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Corn Earworm Control Studies in Virginia[1]

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The degree of success obtained in the control of the corn earworm *Heliothis armigera* (Hbn.) depends on, in addition to the insecticide used, a number of factors which are closely associated with the complex ecology of this pest. This is especially true in the Norfolk area of Virginia where population levels are extremely heavy and where the tendency towards the formation of peak levels, or broods, is poorly defined and often completely lacking. Corn earworms infest sweet corn in this area from the earliest to the latest plantings and all stages of the worms are present throughout most of the season. Results obtained through the application of numerous insecticides in 1948 indicate very clearly that materials used successfully elsewhere do not perform as successfully in Virginia, nor do they produce consistent results throughout the season.

The varying degrees of corn earworm control reported in this paper appear to be of secondary importance. They serve only as a guide to the more promising insecticides, and insecticidal formulations, for use in future work. Of far greater significance are the underlying factors, not clearly understood at this time, responsible for the variable and unpredictable results obtained.

Procedure.—With the exception of the first test made, all materials were applied by means of a rotary hand duster at approximately 30 to 35 pounds of dust per acre, per application. The plots were replicated at random three or four times, depending on the amount of space available, and because of the system used in planting, two row plots, each 50 feet in length, were employed. The dusts were applied only to that general portion of the plant in which the silk appears and treatments were begun when the greater part of the plants in any one variety had been in silk for about 4 days. The Aristogold variety proved to be a very poor test plant in this respect since it silks unevenly and often requires several pickings commercially. Three dust applications were made at 2 or 3 day intervals, except in cases where unfavorable weather conditions warranted a fourth application or a wider interval between treatments. Samples were collected when the ears for each variety were in their most desirable marketing condition. In scoring earworm injury, the husk was stripped back for approximately half the length of the ear and the following classes of injury were noted: *clean*—if free from earworms or earworm injury; *slight*—if containing newly hatched earworm larvae or showing slight feeding on a few of the tip-most kernels; *medium*—if injury occurred on not more than an inch and a half of ear tip; and *heavy*—if the injury exceeded more than an inch and a half of the ear tip or appeared to any degree below the inch and a half line.

Table 1.—Comparative earworm control. Dusts applied June 22, 25, 29 and corn harvested July 6, 1948.[1]

Treatment	Marketable Ears per 100 Ears—Carmel Cross
DDT 3%	80.0
Parathion 1%	58.0
Ditolyl trichloroethane[2] 5%	20.7
Benzenehexachloride[3] 1% Gamma	30.7
Piperonyl cyclonene 0.5%—Pyrethrine 0.04%	27.3
Untreated	19.3
Difference required for significance, 5% level	21.4

[1] Treatments made with American Beauty Puff Duster.
[2] *Gytol.*
[3] Improved, odorless benzene hexachloride. Dow Chemical Company.

Table 2.—Comparative earworm control. Dusts applied July 5, 7, 9 and corn harvested July 19, 1948.

Treatment	Marketable Ears per 100 Ears—Aristogold
DDT 3%	68.0
Parathion 1%	58.0
Benzenehexachloride 1% Gamma	27.0
Dichlorodiphenyldichloroethane 3%[1]	44.0
Untreated	15.0
Difference required for significance, 5% level	16.0

[1] *Rhothane.*

[1] Acknowledgement is made to the following companies for providing materials used in these tests: Geigy Co., Inc., American Cyanamid & Chemical Corporation, Pennsylvania Salt Manufacturing Co., Dow Chemical Company, McLaughlin Gormley King Co. and Rohm and Haas Co.

Table 3.—Comparative earworm control. Dusts applied July 9, 12, 17 and corn harvested July 23, 1948.

Treatment	Marketable Ears per 100 Ears	
	Ioana	Golden Cross Bantam
Parathion 1%	41.0	44.0
Parathion 2%	69.0	82.0
DDT 3%	25.0	65.0
Dichlorodiphenyldichloroethane 3%	18.0	42.0
Untreated	10.0	12.0
Difference required for significance, 5% level	12.0	14.2

Table 4.—Comparative earworm control. Dusts applied July 22, 24, 26 and corn harvested August 6 (Ioana) and August 9 (other varieties) 1948.

Treatment	Marketable Ears per 100 Ears		
	Ioana	Aristo-gold	Golden Cross Bantam
DDT (Regular) 3%	39.0	41.0	54.0
DDT (Impregnated) 3%[1]	92.0	82.0	83.0
DDT (Impregnated) 1%[1]	55.0	47.0	65.0
Parathion 2%	95.3	75.0	96.3
Untreated	0.0	2.0	0.0
Difference required for significance, 5% level	12.2	10.2	18.0

[1] Made from DDT concentrate.

Clipping of the ears is usually practiced with untreated sweet corn emanating from Virginia farms, but for practical purposes, corn in either of the first two categories is considered as being free from the need of clipping and together constitute the "marketable" ears referred to in the tables of this paper.

RESULTS OBTAINED.—Tables 1 to 4 show the number of ears out of 100 that were found to be marketable, those which required no special processing such as clipping.

DISCUSSION.—The total inadequacy of a number of the materials used, or in some cases the use of too weak a formulation of an otherwise good insecticide, is apparent. The good showing made by 1 per cent impregnated DDT is encouraging and had it been included along with materials used in the experiment shown in table 1, it might have given results of outstanding value under conditions which appeared to be normal for the earworm over most of its range. Parathion 2 per cent and impregnated DDT 3 per cent produced excellent results and with improved technique or over-all plant treatment should be highly useful in combatting corn earworm in this area.

These data for corn earworm control are not important in themselves. Of greater importance are the inferences drawn from them. The effect of variable populations seems not to have been introduced into these data since the degree of infestation remained at a high level throughout the entire season and no one experiment had the advantage of operating at a time when earworms were at a low ebb. The fluctuations in degree of control obtained at different times in the season, more noticeable for 3 per cent DDT than for any single material, are believed to be closely associated with the site chosen for oviposition. The data indicate that better control is undoubtedly obtained when dusting only the silks, if the majority of eggs are deposited on the silks. Eggs deposited elsewhere on the plant, as occurs commonly in Virginia after the first plantings have become infested, pose a serious problem in earworm control since earworm larvae originating from eggs laid at random upon the whole plant can enter the silks as soon as they appear. It becomes increasingly important, therefore, to make one dust application just prior to silking in order to eliminate that portion of the population which would normally infest the ears before standard post-silking treatments were begun. This belief is supported by numerous observations in which even the complete removal of silk by Japanese beetle adults resulted in not more than 50 per cent clean ears in untreated corn.

The corn varieties selected for these studies were so chosen because they were readily infested by earworms. Aside from the degree of palatability inherent in any given variety of corn, table 3 indicates rather clearly the influence such physical weaknesses as loose and short husks can exert on degree of control obtained. Ioana is one variety with very poor husk characteristics as far as corn earworm infestation is concerned.

In one large scale field experiment, not reported here because of heavy Japanese beetle feeding in many of the plots, various timing studies were made. The materials used agreed in every respect with those already reported, but the most interesting point brought out was the complete lack of uniformity in control based on the number and date of dust applications. The application of one dust, in all cases the first of a series of three starting 4 days after silking, resulted in no appreciable control. Any combination of two dusts resulted in control comparable to those plots receiving all three applications. The expected reduction in control resulting from the intentional delay of a series, that is, starting a series 7 days after silking instead of the usual 4-day period, did not materialize in many instances.

CONCLUSIONS.—These data indicate that DDT and parathion are the most promising of the materials tried for earworm control. A 3 per cent DDT dust is not strong enough to control the earworm in this part of its range where populations are large and where there is little evidence of distinct broods. Impregnated DDT dusts offer much hope for future control work and of lessening the residue where the stalks are used for cattle feed. The variation in degree of control obtained by the test materials used in 1948 points to the influence of such factors as varietal preference, inherent physical characteristics of varieties other than palatability, and oviposition habits as affected by condition of the host plant. The extremely high earworm populations in the Norfolk area of Virginia tend to accentuate all of these factors. Random counts have shown as high as 22 newly hatched larvae in the silk channel and as many as 53 eggs on the silk of a single ear.

The Green Peach Aphid as a Pest of Tobacco[1]

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Aphids on tobacco in North Carolina have become increasingly abundant during the past few years. Heretofore, aphids (plant lice) have been observed on tobacco but not in numbers sufficient to be considered injurious. Consequently, control measures have not been deemed necessary. A severe outbreak in 1948 necessitated some immediate insecticidal control information. The present paper is a brief of preliminary tests for aphids as tobacco pests.

HISTORICAL.—Pergande (1898) described a supposedly new species, *Nectarophora tabaci*, of aphid found on tobacco. Howard (1898) had reported this same species as infesting experimental plots of tobacco. Patch (1925) stated that Pergande's species is a synonym of *Macrosiphum solanifolii* (Ashmead).

Evidently, the green peach aphid, *Myzus persicae* (Sulzer), has been known as a pest of tobacco for a number of years. In Sumatra, den Doop had reported it as an economic pest as early as 1919. The life history and economics of *Myzus persicae* as a pest of tobacco in Sumatra were described by de Jong in 1929. Kuijker *et al.* (1930) reported on derris as a control for this pest in Sumatra.

Farmers in North Carolina have noted aphids on field tobacco for at least the past ten years. A survey made among some eastern North Carolina growers showed that aphids had been noticed on tobacco long before 1946 but that they were never abundant enough to be considered as pests. In 1946 heavy aphid infestations were reported from numerous sections of eastern North Carolina. In 1947, reports of serious infestations were more numerous and they came from a wider area. A survey in May 1948, indicated that heavy infestations might be expected. By early June, heavy infestations were being reported throughout eastern North Carolina. A month later, aphid damage was noted in the Piedmont area and west to the burley-producing areas in the western part of the state. The peak of the 1948 outbreak in eastern North Carolina occurred about the last week in June.

SPECIES INVOLVED.—There has been some question as to the aphid species infesting tobacco in North Carolina. Specimens collected from field tobacco in eastern North Carolina have been deter-

[1] Contribution from the Department of Zoology and Entomology, N. C. Agr. Expt. Sta. Presented with the approval of the Director as paper no. 318 in the Journal Series.

mined[1] as the green peach aphid, *Myzus persicae* (Sulzer). This species has a number of host plants. Horsfall (1924) lists 106 different host plants recorded from various authorities as well as an account of its life history in Pennsylvania. Gillette & Taylor (1908) record tobacco as a host plant in the greenhouse but do not list tobacco as a host plant in the field. The life history of this species and a complete list of its host plants in North Carolina are not known completely.

DESCRIPTION OF DAMAGE TO TOBACCO.—Tobacco can be injured by the feeding of the aphids in two ways, (1) by the sucking of plant juices and (2) by the deposition of undesirable honeydew excretions upon the plant. The sucking of plant juices leaves the tobacco leaf thin, and it is impossible to cure it out to the desired yellow color. Heavily attacked leaves are said to lose weight thus reducing the yield per acre.

The deposition of honeydew, though an indirect source of damage, may be more serious in some cases than the actual feeding by aphids. When aphids are as numerous as 2000 per leaf, their honeydew may entirely cover some leaves. Black, sooty molds grow on the honeydew causing the leaf to appear unsightly. Frequently, the cast skins of lady bird beetle larvae may collect on such leaves. The leaves thus covered usually cure out a dark brown or black color and are brittle. Such leaves are of poor quality and command a corresponding low price on the market floor.

CONTROL TESTS.—Preliminary tests for aphid control were conducted on mature field-grown tobacco in 1947 (Kulash 1948). Results of these tests indicated that a spray of 40 per cent nicotine sulfate (one part of 40 per cent nicotine sulfate to 800 parts of water, by volume) was not an effective control. Other materials tried in these tests included (1) an 0.8 per cent gamma benzene hexachloride dust made from a 6 per cent gamma technical grade benzene hexachloride dust concentrate; (2) a combination dust of 1 per cent gamma benzene hexachloride and 5 per cent DDT, (3) 5 per cent toxaphene dust, (4) 5 per cent chlordan dust, (5) a 1.0 per cent tetraethyl pyrophosphate spray. The combination dust of 1 per cent gamma benzene hexachloride and 5 per cent DDT appeared to be the most effective 5 days after application. The 1 per cent tetraethyl pyrophosphate spray was effective immediately after application but it did not prevent an aphid re-infestation 5 days after application.

In the 1948 tests, a total of 10 dust and spray formulations were used. These materials and their effectiveness for aphid control are listed in table 1. Heavily infested plants, with as many as 1000 or more aphids per leaf on the top four leaves of the plant, were selected for the tests. The average number of aphids per square inch of leaf surface was estimated in each plot before treatment. One day after treatment, all plants were examined again. The effectiveness of the insecticide was determined by the number of live aphids present at the time of this count. The designation "good" control indicates that there were approximately 50 aphids per leaf; "very good," 25 aphids per leaf; "excellent," no aphids present (or complete control); and "poor," apparently little or no reduction in aphids.

Insecticides were applied as dusts, sprays, and aerosols. Dusts were applied to both sides of the leaves with a plunger-type duster at about 30 pounds per acre. Sprays were applied with a garden-type compressed air sprayer at about 80 gallons per acre. Aerosols were applied directly to the top of the plant through the top of a cone-shaped shield, 10 inches in diameter at the top and 20 inches in diameter at the bottom, which served as a means of confining the aerosols near the plant. Aerosols contained in five pound "bombs" were applied at the rate of two seconds per plant. Each material was used one time only. Applications were made in the morning after the dew had dried.

DISCUSSION.—The quickest kill of aphids was obtained with the 1.0 per cent tetraethyl pyrophosphate aerosol. In all plants treated with this aerosol, the aphids evidently were killed so rapidly that they did not fall from the leaf on which they were feeding. All the other aerosols were effective but not superior to the dusts or sprays used except for the 0.2 per cent rotenone—0.8 per cent piperonyl cyclonene dust which was not effective. It is felt that improvements in methods of application must be made before aerosols can be economically used for aphid control

[1] Determinations made by Dr. C. F. Smith, Research Entomologist, North Carolina Agricultural Experiment Station.

Table 1.—Summary of results for aphid control on tobacco, 1948.

FORMULATION	MATERIAL USED	RATE OF APPLICATION PER ACRE	NUMBER OF APHIDS PER LEAF ONE DAY AFTER TREATMENT
Spray	20% tetraethyl pyrophosphate 1 qt./100 gals. water	80 gals.	25
Spray	25% gamma benzene hexachloride (purified odorless form) 1.5 lbs./100 gals. water	80 gals.	50
Dust	1.5% gamma benzene hexachloride (purified, odorless form)	30 lbs.[1]	50
Dust	1% parathion	30 lbs.[1]	0
Dust	0.66% tetraethyl pyrophosphate	30 lbs.[1]	0
Dust	0.2% rotenone—0.8% piperonyl cyclonene	30 lbs.[1]	1,000
Aerosol	1.0% rotenone—0.2% pyrethrins— 3.0% piperonyl butoxide, 10% methylated napthalene, 82% carrier[3]	—[2]	50
Aerosol	10% DDT— 40% methylene chloride 50% methyl chloride	—[2]	50
Aerosol	5% DDT—5% chlorinated camphene 40% methylene chloride 50% methyl chloride	—[2]	50
Aerosol	1% tetraethyl pyrophosphate 1.5% other organic phosphates 97.5% methyl chloride	—[2]	0
	Untreated check		1000 or more

[1] Estimated.
[2] Aerosols applied at rate of 2 seconds per plant.
[3] *Freon 12.*

on tobacco. Foliage burn resulted if the outlet nozzle of the bomb was held too close to the plant. Despite the cone-shaped cover, it was difficult to get a good coverage with the aerosol to both sides of the leaf principally because of slight gusts of wind.

Of the other materials used for aphid control, the 1 per cent parathion dust seemed to be the most effective, followed by the tetraethyl pyrophosphate spray. Aphids did not reinfest plants treated with 1 per cent parathion dust as soon as they reinfested plants treated with any one of the tetraethyl pyrophosphate formulations.

The effectiveness of benzene hexachloride (purified, odorless type), dust or spray, was rated "good." These formulations were not as rapid killers of aphids as were the tetraethyl pyrophosphate formulations. However, the former had a longer residual effect than did the latter.

The test tobacco was harvested and cured in the normal manner for flue-cured tobacco. The first priming of leaves took place on July 22. There were three successive primings at weekly intervals after the first. In regard to time of insecticidal application, the first priming took place three weeks after the test treatments.

The cured tobacco is being analyzed for treatment residues but not all data are available at this time.

NATURAL CONTROL.—The incidence of various predators feeding on aphids may result in a high degree of natural control in many fields. The four major predators observed this past season were:

(1) Lady bird beetles—larvae and adults (several species, family Cocinellidae).
(2) Larvae of syrphid flies (several species family Syrphidae).

(3) Nymphs and adults of the stilt bug *Jalysus spinosus* (Say).
(4) Lace wing larvae (aphis lions) (family Chrysopidae).

In several fields in Wake County it was not unusual to find larvae, or nymphs, and adults of all four of the above groups in the same field feeding on aphids on the same plant. Many tobacco growers have learned to gauge the abundance of these predators on their tobacco and thereby rely on them for control. However, when infestations of aphids are heavy and there are no attendant predators, then insecticidal treatments must usually be resorted to for control.

The effect of temperature and moisture upon the abundance and distribution of aphids in the tobacco is not clearly understood. Observations this past season showed that infestations usually started in the low and wet spots of a field. Fields bordered by woods if infested were usually found to be infested first near the woodsside of the field. Aphid populations were observed to have decreased in different sections of the state under either set of weather conditions. In one field where no chemical or other control measures had been applied, aphids were not present in the sunny portions of the field but were present on tobacco in the shade of trees. Aphids in such shady spots continued to live days after aphids in sunny spots had disappeared or died, despite the fact that aphids in shady spots were being heavily fed upon by larval and adult lady beetles. Gould (1930) noted that *Myzus persicae* disappeared completely in Virginia in a hot and dry summer.

SUMMARY.—The common green peach aphid, *Myzus persicae* (Sulzer), has been a pest of field-grown tobacco in North Carolina for the past several years. Damage in 1947 was more severe and widespread than any recorded in previous years. A severe outbreak occurred in 1948 throughout eastern North Carolina and well into the western part of the Piedmont area.

Of 10 different insecticidal formulations used, 1 per cent tetraethyl pyrophosphate in aerosol form killed aphids more rapidly than any of the other formulations tried but it did not have any residual effect. Parathion dust, 1 per cent was next to the 1 per cent tetraethyl pyrophosphate in respect to rapidity of kill. Parathion dust, 1 per cent, was more effective than any of the other formulations tried from the standpoint of residual effect. The other materials used included a spray made from the purified, odorless form of gamma benzene hexachloride; tetraethyl pyrophosphate dust, a rotenone piperonyl cyclonene dust, and the following aerosols—10 per cent DDT, 5 per cent DDT—5 per cent chlorinated camphene, and 1 per cent rotenone—0.2 per cent pyrethrins—3 per cent piperonyl butoxide. Foliage burn occurred where the aerosol bomb outlets were held too close to the plant. The other formulations, sprays or dusts, did not cause any foliage burn.

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SCIENTIFIC NOTES

The Diamondback Moth in Pennsylvania[1]

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Comparatively little is known concerning the abundance and distribution of the diamondback moth *Plutella maculipennis* Curtis in North America. It is a cosmopolitan species occurring probably everywhere cruciferous crops are grown and is known from Europe, India, Africa, New Zealand, the Hawaiian Islands, South and North America. Most of the records from this country are from California and southern United States although it has been reported from Canada, New York, Pennsylvania and New Jersey. This insect has been found in every province of Canada but apparently is not a major problem in the far North. It is believed that it originated in the Mediterranean area where its hosts the Brassicas had their origin. This species does not develop well in hot or cold climates but is best adapted to temperate areas.

The life history of the diamondback moth varies in different parts of the world and these variations have much to do with the flight of the moths and their reaction to lights. In the temperate climate the species hibernates chiefly as adults and possibly in some places as pupae. In the warmer parts of the country there is no hibernation period and the species is active during the entire year. There are several generations a year, seven occur in Colorado and as many as 11 in warmer areas. There are apparently six generations of the diamondback moth in Pennsylvania. The moths were in flight almost constantly during the operation of the traps from May 23 to September 12 and undoubtedly were on the wing for a longer period than that indicated by these records. The generations are indicated by the daily flight records shown in chart I where curves are plotted for 2 and 5-day intervals. The adults live for a considerable period of time. Under normal conditions females survive for 11 or 12 days. Given (1944) states that the adults, properly fed on honey or bee bread and honey, will live for 90 to 100 days. These factors account for the almost continuous flight of the moths from May to November in temperate climates and throughout the year in warmer areas. It is believed by some that the first generation, in the North, may breed on wild Cruciferae and the later generations migrate to cultivated crops.

The diamondback moth is a night flier and is freely attracted to lights. In our work, New Jersey mosquito light traps were used to attract them. The traps were equipped with a 25 watt bulb and with a motor and fan producing a down draft of approximately 400 feet per minute. In special tests, 60 and 100 watt lamps did not seem to increase the catches. Twenty light traps were operated in widely separated parts of Pennsylvania representing crop, forest, suburban areas and locations near reservoirs and large lakes. The wide selection of areas was made because the traps were operated to intercept many other species of insects. In most cases the collections were made daily by cooperators and mailed to State College for separation and identification.

Diamondback moths are small and go through the fan of the trap with much less injury than larger moths. They are easy to recognize and the error in separating and counting them from thousands of other insects was considered very small. Specimens were generally obtained in excellent condition. On rare occasions, when the cyanide jar was permitted to become moist, the adults were injured and difficult to identify. Care should be exercised not to confuse the diamondback moth with *Monopis dorsistrigella* Clem. which superficially resembles it and is also attracted to lights freely. *M. dorsistrigella* has more or less diamond-shaped, pale marks on the dorsum but is not as slender and is usually darker in color than the diamondback moth. The diamondback moth is paler in color, the wings are more pointed and the antennae are distinctly banded.

Although light traps have been operated by numerous workers to attract Lepidoptera, little information seems available on the attraction of the diamondback moth. This is probably due to the fact that most entomologists have been interested chiefly in catching the larger moths such as the Noctuidae, Pyralididae and Geometridae. The microlepidoptera, because of their small size, have been quite generally overlooked. Turner (1918) gives figures on light trap catches which indicate that male and female diamondback moths are attracted in about equal proportions. It is surprising that the extensive trap-lantern records by W. M. Forbes (1923–1925) include no mention of *Plutella maculipennis*. Aside from these figures the writer has been unable to locate definite records of the attraction of diamondback moths to light.

Low temperatures and excessive air currents seem to be the two main factors affecting the flight of the diamondback moths. List (1937) accounts for variations in moth populations chiefly on the basis of wind velocity. Hardy (1938) shows that breeding occurs freely between 50° and 104° F. while adults were active up to 122° F. This tolerance probably accounts for the wide distribution of this species.

A correlation of the moth flight for 1948 with climatic conditions revealed little or no direct relation. Hourly temperatures, precipitation and wind velocities were calculated for the twelve hour period from 8 P.M. to 7 A.M. corresponding to the period of operation of the traps.

During the operation of the traps, the wind velocity was generally low, averaging 4.19 miles per hour and exceeding 10 miles per hour on only three evenings. Checking low catches against wind velocities revealed nothing significant. On the other hand some of the largest catches were taken on evenings with comparatively high wind velocities. For example, 26 moths were taken on June 24 with an average wind velocity of 5.9 miles per hour and 26 moths were taken on June 29 with an average wind velocity of 6.7 miles per hour. High wind velocities may affect the catches, chiefly by forcing the small moths from a particular area.

Table 1.—Populations of larvae on cabbage, State College, Pa. Sept. 16, 1948.[1]

	Number	Per Cent
Cabbage loopers	16	11.7
Imported cabbage worm	114	83.2
Diamondback moth	7	5.1

[1] Figures taken by Dr. L. E. Dills.

[1] Authorized for publication on February 28, 1949 as paper No. 1514 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

The precipitation was moderate during the summer of 1948. The greatest rainfall, .84 inches, occurred on June 19 and July 23. There was no appreciable reduction in moth catches on either of these nights. On the contrary relatively large collections were made on evenings with considerable rain. Twenty-four moths were taken on May 29 when .62 inches of rain fell.

The temperature, other climatic factors being moderate, is undoubtedly the most important factor affecting the flight of the diamondback moth. The low catches from May 23 to 27 with temperatures below 60° F. are significant. The lack of catches on June 6 and June 17 are largely due to low temperatures although the former is partly due to the interval between generations.

During 1947 and 1948 diamondback moths were taken in light traps from 20 localities and 14 counties in Pennsylvania. They were common in the central and eastern portions of the state but rare in the western and northern parts. The lack of abundant plantings of cruciferous crops in certain areas such as the wooded areas of Potter, Forest, Monroe and Beaver counties no doubt accounts for the low catches in these areas. These differences are especially noticeable in comparing the collections from the various localities of eastern Pennsylvania. Adults were rarely taken at Buck Hill Falls, a forested area, but were common from all other eastern localities.

It is generally considered that the larvae of the diamondback moth are small and that the species therefore causes little or no damage to cabbage and related plants. Harrison and Brubaker (1943) indicate that the larvae of the cabbage looper and the imported cabbage worm are generally more abundant than those of the diamondback moth. His population studies were made in the fall when these species are at the height of their development. Counts taken at State College, Pa., show similar conditions although light trap catches from the same area during the middle of the summer show high infestations (Table 1).

The diamondback moth, in the northern parts of its range, reaches its peak during the middle of the summer and a count at this time would show a larger proportion. Smith & Brubaker (1938) show that at Baton Rouge, La., the population of the diamondback moth is much larger than that of the other two species from October to May. The diamondback moth must therefore be considered a factor in the South. The accompanying figures indicate that it may at times reach proportions in Pennsylvania to warrant consideration.

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Boll Weevil Control with Several Organic Insecticides During 1948

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Experiments with several organic insecticides for the control of the boll weevil, *Anthonomus grandis* Boh., were continued during 1948 at the Florence laboratory and the results are briefly discussed herein.

METHOD.—Four randomized-block experiments were conducted in small field plots, ranging from 0.1 to 0.2 acre. Each test consisted of six insecticidal treatments and an outside check replicated four times.

Five large-scale experiments were conducted with three commercially mixed insecticides, namely, (1) 20 per cent of toxaphene plus 40 per cent of sulfur, (2) 5 per cent of DDT plus sufficient benzene hexachloride so that the dust contains 3 per cent of the gamma isomer plus 56 per cent of sulfur, and (3) 10 per cent of chlordan plus 5 per cent of DDT plus 40 per cent of sulfur. The plots ranged from 0.25 to 1.75 acres. With one exception each treatment and a check were replicated twice in each field; the exception was not replicated. All the replicated tests were arranged in randomized blocks.

In the nonreplicated field the dust was applied by a 5-row tractor duster, while in the other fields rotary hand dusting machines were used. The dust applications were usually made early in the morning, when the plants were wet with dew and the air for the most part was calm.

Each treatment was applied on nine plots—on two at 3-day intervals, on one at 5-day intervals, and on six at 7-day intervals. Yields were estimated by harvesting 0.025 acre in each of the small plots and 0.1 to 0.14 acre in each of the large plots.

Boll weevil infestation records were made at about 5-day intervals until the crop was mature. Records were also made on the abundance of aphids and red spiders, but they were not numerous enough to influence the results in any of the tests; therefore, these records are not given. A moderate infestation of the bollworm occurred in experiment 4, but only a very light infestation of this insect was present in the other tests.

RESULTS OF SMALL-PLOT EXPERIMENTS.—In experiment 1 the dusts containing 2 and 3 per cent of the gamma isomer of benzene hexachloride plus 5

[1] In cooperation with the South Carolina Agricultural Experiment Station.

Table 1.—Results of four small-plot experiments with various organic insecticides for boll weevil control. Florence, S. C., 1948.

Treatment	Rate of Application per Acre	Seasonal Average of Punctured Squares	Yield of Seed Cotton per Acre	
			Total	Gain over Check
	Pounds	*Per Cent*	*Pounds*	*Pounds*
Experiment 1—8 applications beginning at 28% infestation, 9 records				
Benzene hexachloride (technical):				
Gamma 3% plus DDT 5%	8	24	1225	519
Gamma 2% plus DDT 5%	9	24	1245	539
Gamma 1% plus DDT 5%	8	30	955	249
Gamma 1% plus DDT 10%	9	29	938	232
Toxaphene 10% plus DDT 5%	9	28	1013	307
Chlordan 10% plus DDT 5%	9	25	1017	311
Check (no treatment)	—	44	706	—
Experiment 2—9 applications beginning at 16% infestation, 5 records				
Chlordan:				
20%	12	41	1475	550
10%	10	50	1268	343
10% plus DDT 5%	9	50	1475	550
10% plus DDT 5% plus parathion 1%	11	41	1554	629
10% plus DDT 5% plus rotenone 1%	10	42	1544	619
5% plus DDT 5% plus parathion 1%	10	48	1386	461
Check (no treatment)	—	65	925	—
Experiment 3—7 applications beginning at 34% infestation, 8 records				
Toxaphene:				
20%	10	27	1602	667
20% plus rotenone 1%	10	27	1680	745
20% plus parathion 1%	10	24	1724	789
20% plus sulfur 40%	11	26	1721	786
20% plus sulfur 40% plus parathion 1%	11	19	1643	708
10% plus parathion 1%	8	32	1611	676
Check (no treatment)	—	41	935	—
Experiment 4—16 applications beginning at 10% infestation, 9 records				
Toxaphene:				
20% plus parathion 0.5%	13	40	1326	1310
5% plus chlordan 5% plus DDT 5% plus parathion 0.5%	10	47	862	846
Chlordan:				
20% plus parathion 0.5%	12	49	640	624
10% plus DDT 5% plus parathion 0.5%	11	56	841	825
Benzene hexachloride (technical):				
Gamma 3% plus DDT 5% plus parathion 0.5%	11	34	1288	1272
Gamma 2% plus DDT 10% plus sulfur 40% plus solvent 2.3%	11	40	1298	1282
Check (no treatment)	—	87	16	—

per cent of DDT gave the best boll weevil control and the highest yields (Table 1). A mixture containing 1 per cent of the gamma isomer plus 5 or 10 per cent of DDT was not strong enough to give good weevil control. Toxaphene and chlordan at 10 per cent strength plus 5 per cent of DDT were about equal in controlling the boll weevil and increasing the yield, but they were less effective than a benzene hexachloride dust containing either 2 or 3 per cent of the gamma isomer.

In experiment 2, 20 per cent of chlordan gave better boll weevil control and a higher yield than did 10 per cent. The addition of 5 per cent of DDT to 10 per cent of chlordan did not increase the boll weevil control, but it increased the yield, probably owing to additional control of other injurious insects. Moreover, the addition of 1 per cent of parathion or 1 per cent of rotenone to the latter mixture gave slightly higher yields.

In experiment 3 good boll weevil control and high increases in yield were obtained in all treatments. All the mixtures gave somewhat higher yields than toxaphene at 20 per cent when used alone.

Experiment 4 was conducted in a cotton field planted on June 10, or about 2 months later than the average planting date. The boll weevil infestation was very high, owing principally to a continuous heavy influx of weevils from the surrounding area. A moderate infestation of the bollworm and a light infestation of the red spider were also present. A total of 16 applications were made at about 3-day intervals between June 28 and August 15.

For late-season weevil control the results were outstanding (Table 1). The best boll weevil control

Table 2.—Results of large-plot (0.25 to 1.75 acres) experiments with three commercial insecticides applied at various intervals for boll weevil control. Florence, S. C., 1948.

Treatment	Squares Punctured				Yield of Seed Cotton per Acre				Average Gain in Yield per Acre
	3-Day Interval	5-Day Interval	7-Day Interval	Average	3-Day Interval	5-Day Interval	7-Day Interval	Average	
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
DDT 5% plus benzene hexachloride (technical) gamma 3% plus sulfur 56%	32	28	38	33	1578	1739	1466	1594	811
Toxaphene 20% plus sulfur 40%	27	45	32	35	1488	1833	1554	1625	842
Chlordan 10% plus DDT 5% plus sulfur 40%	33	26	41	33	1493	1770	1424	1562	779
Check (no treatment)	80	67	50	66	17	1142	1189	783	—

was obtained with a dust containing 3 per cent of the gamma isomer of benzene hexachloride plus 5 per cent of DDT plus 0.5 per cent of parathion followed closely by 20 per cent of toxaphene plus 0.5 per cent of parathion and by a dust containing 2 per cent of the gamma isomer plus 10 per cent of DDT plus 40 per cent of sulfur plus 2.3 per cent of an unknown solvent. These treatments also gave the highest yields.

With the exception of the treatment containing 20 per cent of chlordan plus 0.5 per cent of parathion, all treatments gave good bollworm control. This lack of bollworm control was the reason for the low yield in this treatment.

A moderate to light infestation of the red spider, *Tetranychus atlanticus* McG., developed after all treatments with the exception of the one containing 40 per cent of sulfur. These data would indicate, therefore, that 0.5 per cent of parathion in every application of the various mixtures was not sufficient for good control of the red spider.

Results of Large-Plot Experiments.—In the large-scale experiments the three commercial mixtures of insecticides gave about the same degree of boll weevil control and nearly equal yields (Table 2). The increase in yield averaged about 800 pounds of seed cotton per acre, or approximately 100 per cent gain over the untreated check plots, for each of the three mixtures.

Higher yields and better boll weevil control were obtained at the 3- and 5-day intervals of application than at the 7-day interval.

From observations in the large-plot experiments it now appears that the interval of application cannot be extended beyond 5 days for good boll weevil control during midseason or late season.

Screw-Worm Survey in Western United States, 1948

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The annual survey of screw-worms, *Callitroga americana* (C. & P.), conducted by the United States Bureau of Entomology and Plant Quarantine in cooperation with state extension specialists, was begun in March 1948 to determine the winter-survival areas of this insect in Texas and Arizona. The screw-worm rarely survives the winter in other states west of the Mississippi, except possibly in California. Later in the season, when the fly had spread from the winter-survival areas, the survey was extended to New Mexico, Oklahoma, Louisiana, Arkansas, Missouri, Kansas, Nebraska, Iowa, and Illinois, all of which are annually invaded by the fly either through natural dissemination or through importation of infested animals. As the survey continued, first through counties and later through states adjacent to the overwintering areas, studies were made of the migration or dispersion of the fly, the intensity of infestation, the inciting factors or causes of outbreaks of screw-worm, and particularly of the amount of Smear 62 that was available locally and that would be needed in the event a sudden and serious outbreak should occur. To obtain the information needed to evaluate the local condition of each county scouted, survey scouts contacted county agents, veterinarians, livestock owners, and dealers in screw-worm remedies.

Within the year surveys were made in almost all the 254 counties in Texas and in approximately half the counties in Arizona, Oklahoma, and Kansas. In each of these states the counties were selected so that all areas and environments were well represented. In New Mexico, Louisiana, Arkansas, Missouri, Nebraska, Iowa, and Illinois fewer counties were surveyed than in the other states, but, here too, the counties represented a good cross-section of the conditions that prevailed in each of these states.

The early scouting in Texas revealed that the winter-survival area of *Callitroga americana* was confined to not more than 10 counties in the extreme southern end of the state. Webb, Duval, and Kenedy Counties were the northernmost counties found to be infested during the winter months. Subsequent scouting during April and early in May indicated that migration of the screw-worm fly was under way but was about two to three weeks later than normal. From April 24 to 30 infestations were reported in Uvalde and Victoria Counties, north and east, respectively, of the winter-survival area. Infestations in the counties through which early migration was progressing was reported as relatively light, ranging from less than 0.1 to approximately 0.3 per cent of the domestic animal population.

In Arizona the winter-survival area of the screw-worm was apparently confined to portions of Santa Cruz, Pima, Yuma, and Maricopa Counties. From all reports received it was evident that the cold of last winter accompanied by a prolonged drought reduced fly activity to such an extent that winter-survival of *Callitroga americana* this year occurred only in the low, sheltered valleys and canyons in the southern part of the state. The first report of spring infestations was received April 13 from near Patagonia, in Santa Cruz County, where young calves became infested. Spring migration of screw-worms apparently started in April and followed the low irrigated valleys northward.

Once the spring migration in Texas got under way, the screw-worm fly spread eastward into Louisiana and Arkansas, northward into Oklahoma and Kansas, and northwestward into eastern New Mex-

ico by mid-summer. Infestations in Missouri, Illinois, Iowa, and Nebraska were undoubtedly due to importation of infested animals, many of which had been brought into these states early in the season. It was also revealed that early infestations were started in Kansas as a result of importing infested animals. This condition has been observed there every year since the survey was started in 1943, and is always traceable to places where southern animals are brought in for consignment to packing houses for slaughter or where the animals that are in transit to this or other states are held temporarily in sales or in feeding and resting stations.

No serious infestations developed this season in any of the affected western states, from infestations imported early in the season, because livestock owners or handlers were watching for such importations and destroyed most of them before the screw-worms could complete their life cycle. These early-season importations of screw-worms reach these states months before the flies that come in through natural migration; therefore, they have ample time to develop a fly population of outbreak proportions before the end of the season unless they are suppressed or wiped out promptly before they can multiply.

Our survey has been particularly effective this year, because the educational work done during previous years has taught the livestock owners and importers how to treat screw-worm cases coming in with southern cattle and thereby suppress or eliminate serious outbreaks later in the season. No heavy infestations were found this year in any of the states that imported infested cattle from the south early in the season and that during previous years have always had screw-worm outbreaks in one or more counties. In one instance 2 years ago, an early importation of screw-worms into a county in one of the midwestern states developed into a serious outbreak by late summer. More than 20,000 screw-worm cases were found in this county, and the infestation had spread to 11 surrounding counties by the end of the season.

Before scouting was discontinued in November, about half the counties in Arizona and in New Mexico were resurveyed to determine the conditions that prevailed in these two states subsequent to the first survey, which was made rather early in the season. No unusual conditions prevailed during the season in Arizona, but in New Mexico heavy infestations during the summer were reported from DeBaca, Guadalupe, Quay, Harding, Colfax, and Union Counties. Apparently these infestations developed as a result of local conditions which were favorable for fly development.

In Texas, where heavy infestations have prevailed almost every year, especially along the Gulf Coast, only light to moderate infestations developed this season. It was definitely the lightest screw-worm year encountered in Texas since the survey was started. Most livestock owners believed that the principal contributing factors to this low screw-worm incidence were the prolonged drought, which was unfavorable for fly development, the prompt treatment of screw-worm cases, and the extensive and rather regular use of the new chlorinated hydrocarbon insecticides for the control of flies, lice, and other insects.

In Louisiana, Arkansas, Missouri, Illinois, Iowa, and Nebraska, only light to very light infestations prevailed in the counties scouted, except in one parish in Louisiana, bordering on the Mississippi, where a rather heavy infestation prevailed during the summer on one or more of the larger plantations. In Arkansas a few of the most southeastern counties were moderately infested early in the summer. Since some of these counties bordered the Mississippi River, it was believed that the infestation also extended across the river into the State of Mississippi, which was not surveyed.

The screw-worm incidence in the western area was definitely very low this season as compared with previous years. As in Texas, many county agents and especially livestock owners throughout this area expressed the belief that the extensive and regular use of the chlorinated hydrocarbon insecticides for the control of lice and flies was responsible for the lower screw-worm incidence. The information obtained by the scouts would indicate, however, that the severe drought and especially the prompt treatment of screw-worm cases with Smear 62, which was abundantly available everywhere, were probably responsible for the low incidence.

The principal object of the survey during the recent war years was to acquaint extension personnel and livestock owners with the superior qualities of Smear 62 for the control of the screw-worm and to see that an ample supply of this remedy, which was then new to the livestock industry, was available at all times. This effort by the personnel making screw-worm surveys has saved many thousands of domestic animals which otherwise would have been lost to the industry and to our nation at a most critical time.

The continuation of the survey since the war has served admirably to further establish the merits of Smear 62 and increase its use, not alone for the treatment of screw-worm cases, but particularly for use in the prevention of screw-worms in all man-made wounds, such as marking, docking, and castrating. The present popularity of Smear 62 for the control and prevention of screw-worms is well illustrated by the sales of screw-worm remedies by one of the largest southwestern manufacturers. The records of this concern, which manufactures both Smear 62 and proprietary remedies, show that of a total of 6,265.5 gallons sold in the western area during the first 10 months of 1948, 90.4 per cent was Smear 62. State extension specialists and county agents have done a heroic job in acquainting the livestock owners with the superior qualities of Smear 62 and inducing them to use it for preventing infestations of, or controlling, screw-worms.

Comparative Effectiveness of Chlorinated Hydrocarbons against the Boll Weevil

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Experiments were designed to determine the comparative effectiveness against the boll weevil, *Anthonomus grandis* Boh., of several chlorinated hydrocarbons applied as dusts on field plots. These tests were conducted on late-planted cotton at Florence, S. C., during the summer of 1948.

MATERIALS.—Three commercial cotton dusts and chlordan and methoxychlor dusts were tested. The commercial dust mixtures were reported to be as follows: (1) Toxaphene 20 per cent plus sulfur 40

[1] In cooperation with the South Carolina Agricultural Experiment Station.

Table 1.—Comparative effectiveness against the boll weevil of several chlorinated hydrocarbon insecticides at different intervals after treatment.

Insecticide	Dosage, Pounds per Acre	Average Number of Dead or Paralyzed Weevils After Hours Indicated							
		2	6	12	24	48	72	144	168
Toxaphene 20% plus sulfur 40%	13	8	39	58	67	80	91	121	135
Benzene hexachloride (technical) gamma 3% plus DDT 5% plus sulfur 56%	19	29	55	63	69	79	91	110	122
Chlordan:									
10% plus DDT 5% plus sulfur 40%	12	9	32	43	52	61	65	81	87
20%	13	8	30	36	43	50	55	72	77
Methoxychlor 20%	15	3	11	19	25	30	34	45	47
Difference required for significance, 5% level		2	5	6	7	8	9	12	13

per cent, (2) enough technical benzene hexachloride to give 3 per cent of the gamma isomer plus DDT 5 per cent plus sulfur 56 per cent, and (3) chlordan 10 per cent plus DDT 5 per cent plus sulfur 40 per cent. The other two dusts were tested at 20 per cent strength in crown clay.

METHODS.—A field was selected into which a heavy influx of migrating weevils occurred during the period of the tests. Two tests were conducted on the same experimental area. It would have been preferable to have conducted these tests on different areas, but there were no other areas of late-planted cotton. The second test was conducted immediately upon completion of the first with the same treatments that were used in the first test. The plots were 0.046 acre in size, and each treatment was replicated four times in randomized blocks.

The dusts were applied with rotary hand guns early in the morning when the plants were wet with dew and the air was fairly calm. Dead or paralyzed boll weevils found on the paper were counted three times on the first day and usually once a day thereafter for 7 days.

The following procedure was used to facilitate counting the dead or paralyzed weevils: A strip of heavy paper 5 feet long and 2 feet wide was placed under the cotton plants on each side of the row. The two strips were pulled together so that the long edges met at the base of the stalks and were fastened together with wire staples. Pairs of strips were placed at eleven locations within each plot, covering a total area of 220 square feet. Similar strips were set out on an untreated check area of the same size.

RESULTS.—Average data from the two tests are shown in table 1. The results of these experiments show that 50 per cent or more of the knock-down and kill by each of the insecticides was effected within the first 24 hours. At the end of 2 and 6 hours the benzene hexachloride mixture had caused a significantly greater knock-down and kill of weevils than had any of the other insecticides. After 144 and 168 hours toxaphene had killed or paralyzed more weevils than the benzene hexachloride mixture, the difference closely approaching significance. There was no significant difference between these two insecticides at any of the other counts. Both knocked down significantly more weevils than any of the other materials tested, except at the 2-hour count.

Methoxychlor killed or paralyzed significantly fewer weevils at each interval for the entire 7-day period than did any of the other treatments. No mortality occurred in the untreated check plots.

No rain fell during either of the tests. The mean temperature was 77° F. for the period of the first test and 79° F. for the period of the second test.

The More Effective Mosquito Repellents Tested at the Orlando, Fla., Laboratory, 1942–47[1]

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Screening tests were made at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine to evaluate 4308 chemicals as mosquito repellents for skin application. *Aëdes aegypti* (L.) was used as the primary laboratory test insect, but most of the compounds were also tested against *Anopheles quadrimaculatus* Say. Detailed data are given for compounds that gave protection for five or more hours against *A. aegypti*. The results with those that gave protection for 3 to 5 hours are also listed with indication as to whether they were more or less effective than the standard dimethyl phthalate.

METHODS.—The method used in the screening tests was adapted from one developed by Granett (1940). The forearm of a research subject was rubbed with 1 ml. of the chemical to be tested and then exposed for 3 minutes in a cage containing several thousand hungry mosquitoes (Morton *et al.* 1947). The arm was withdrawn from the cage, and if there

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development, and from the Office of the Surgeon General, Department of the Army, to the Bureau of Entomology and Plant Quarantine.

[2] Now with U. S. Industrial Chemicals, Inc., Baltimore, Md.

[3] The writers acknowledge the suggestions of E. F. Knipling, then in charge of the Orlando laboratory, and the assistance of various members of the laboratory. Special acknowledgments are due Helen Fluno for assistance with the chemical lists and Lyda Roberson for compiling much of the information from the records. Many of the chemicals listed in this report were obtained from industry, but a number were furnished by workers in various universities, including Nathan L. Drake of the University of Maryland, Melvin S. Newman of Ohio State University, and Paul D. Bartlett of Harvard University. Some were prepared by S. A Hall of the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine.

Table 1.—Compounds effective for 5 or more hours as *Aedes aegypti* repellents, showing for this species and *Anopheles quadrimaculatus* the average length of time to the first bite in all tests and the percentage ratio to the repellent time for dimethyl phthalate in paired tests.

Compound	Chemical Class	*Aëdes aegypti*				*Anopheles quadrimaculatus*			
		No.[1] of Tests	Protection (Minutes)	No.[2] of Tests	Repellent Ratio	No.[1] of Tests	Protection (Minutes)	No.[2] of Tests	Repellent Ratio
Acetyl-α-oximinoacetoacetic acid, ethyl ester	VIII-e	12	339	4	116	12	47	4	19
N-Allyl-4-methylhexahydrophthalimide	VIII-a	5	304	1	30	4	25	—	—
m-Aminobenzoic acid, ethyl ester	VIII-b	7	321	—	—	7	25	—	—
N-*n*-Amyl acetanilide	VIII-a	19	369	7	159	19	55	7	19
N-Amyl butoxyacetamide (*Indimide A*)	VIII-a	7	359	—	—	2	20	—	—
N-(*n*-Amyl)imide of 1,2-dicarboxy-3,6-endomethylene-4-cyclohexene	VIII-a	10	350	4	111	12	54	4	13
N-(mixed Monoamyl)imides of 3,6-endomethylene 4-cyclohexene-1,2-dicarboxylic acid	VIII-a	22	319	7	99	25	26	7	13
N-(*n*-Amyl)succinimide	VIII-a	22	305	10	130	19	176	9	84
Benzoic acid, 1,3-propanediol monoester	IV	7	302	4	83	8	44	4	90
N-iso-Butyl hexahydrophthalimide	VIII-a	8	321	4	137	8	57	4	84
N-*sec*-Butyl hexahydrophthalimide	VIII-a	6	306	2	120	6	48	2	80
N-iso-Butyl-4-methylhexahydrophthalimide	VIII-a	3	359	—	—	—	—	—	—
N-*n*-Butyl propionanilide	VIII-a	8	303	4	88	10	55	4	11
N-iso-Butyl-1,2,3,6-tetrahydrophthalimide	VIII-a	8	357	4	198	8	35	4	65
n-Capric acid	II	18	355	6	117	18	90	6	63
2-(β-Carboxyethyl)-2-ethylhexanal	III	8	309	4	102	8	49	4	15
p-Chlorobenzylfurylcarbinol	IX	2	300	1	116	3	57	1	25
o-Chloro-α-(trichloromethyl) benzyl alcohol	IX	4	357	—	—	6	50	—	—
Citronellic acid	II	4	303	4	96	6	87	4	58
2-(β-Cyanoethyl)-2-ethylbutyraldehyde	VIII-c	12	302	4	174	12	93	4	152
2-Cyclohexylcyclohexanol	VII	27	304	2	93	14	40	2	87
N-Cyclohexyl methallyloxyacetamide	VIII-a	4	319	—	—	4	21	—	—
β-Decalol	VII	16	338	6	144	16	102	6	20
N,N-Diethylglutaramic acid, methyl ester	VIII-a	8	300	4	95	8	48	4	19
N,N-Diethylsuccinamic acid, *sec*-butyl ester	VIII-a	7	358	4	125	8	46	4	19
N,N-Diethylsuccinamic acid, *n*-propyl ester	VIII-a	45	322	5	108	47	61	5	66
2,6-Dimethyl-3-(2-hydroxyethoxymethyl)-tetrahydropyran	V	19	303	11	108	19	38	11	38
N,N-Di-iso-propyl adipamic acid, methyl ester	VIII-a	16	324	—	—	10	51	—	—
N,N-Dipropylsuccinamic acid, *sec*-butyl ester	VIII-a	8	318	4	68	8	38	4	64
N,N-Di-iso-propylsuccinamic acid, propyl ester	VIII-a	8	341	4	116	8	42	4	67
N,N-Di-iso-propylsuccinamic acid, iso-propyl ester	VIII-a	11	310	4	121	12	39	4	87
2,5-Endomethylene-6-methylhexahydro-benzyl diethylene glycol ether	V	11	379	—	—	5	113	—	—
2-Ethylhexaldehyde glyceryl acetal	V	14	320	6	103	14	54	6	48
2-Ethyl-1,3-hexanediol	VII	241	331	9	112	154	53	9	49
4-Ethyl-3,5-octanediol	VII	10	336	6	118	10	47	6	34
Fenchloic acid	II	4	358	—	—	—	—	—	—
Glycerol mono-iso-amyl ether	V	12	305	2	152	12	72	2	105
Hexaldehyde glyceryl acetal	V	10	351	6	116	10	100	6	71
α-Hydroxy-iso-butyric acid, 2-phenyl-ethyl ester	IV	36	341	7	153	39	40	7	27
1-Hydroxycyclohexanecarboxylic acid, 2-butoxyethyl ester	IV	16	320	6	128	8	63	4	74
3-(1-Hydroxycyclohexyl)-2-propen-1-ol	VII	6	335	6	112	6	55	4	44
1-Hydroxycyclopentaneacetic acid, cyclohexyl ester	IV	4	321	2	145	2	54	2	89
2-(*p*-Methoxyphenyl)ethanol	V	21	326	5	185	21	48	5	116
α-Methyl-β-hydroxy-β-phenyl-propionic acid, ethyl ester	IV	18	310	8	93	18	51	8	50
1-Methyl-1,2,3,4-tetrahydro-2-naphthol	VII	10	328	—	—	12	41	—	—
2-Nitro-2-ethyl-1,3-propanediol butanal acetal	VIII-d	25	316	5	132	23	55	5	45
2-Nitro-2-ethyl-1,3-propanediol crotonaldehyde acetal	VIII-d	15	364	4	131	14	63	4	92
2-Phenylcyclohexanol	VII	150	372	9	164	151	76	9	99
1-Phenylcyclohexene-2-ol-1	VII	7	300	3	128	4	128	3	46
β-Phenyl-β-hydroxybutyric acid, iso-propyl ester	IV	8	352	4	78	6	47	4	42
β-Phenyl-β-hydroxy-propionic acid, iso-propyl ester	IV	20	344	8	119	18	42	8	79
Phthalic acid, dimethyl ester (standard)	IV	3406	247	—	—	3512	112	—	—
Phthalic acid, methyl ethyl ester	IV	4	342	—	—	4	18	—	—
Propionic acid, 1,4-cyclohexanediol monester	IV	6	315	4	109	6	47	4	85
N-iso-Propyl-4-methylhexahydrophthalimide	VIII-a	3	359	—	—	3	28	—	—
N-*n*-Propyl-1,2,3,6-tetrahydrophthalimide	VIII-a	12	447	4	180	12	39	4	79
1,2,3,4-Tetrahydro-2-naphthol	VII	74	362	—	—	68	102	—	—
2,4,4-Trimethyl-3,5-octanediol	VII	8	308	4	135	8	57	4	82
dl-Tropic acid, methyl ester	IV	5	306	—	—	5	12	—	—
n-Undecylic acid	II	17	318	—	—	17	115	—	—

[1] Paired tests. [2] Unpaired tests.

were no bites, was reintroduced 20 to 30 minutes later and exposed for another 3 minutes. This procedure was continued as long as there were no bites. The biting rates per half minute were maintained at 50 to 75 for *Aëdes aegypti* and 20 to 25 for *Anopheles quadrimaculatus*.

Each compound was tested first on one arm of several individuals, without direct comparison with the standard (unpaired tests). Most of the materials were also subjected to paired tests, in which the test material was applied to one arm of a subject and dimethyl phthalate to the other. First one arm and then the other was exposed in the same cage, and the protection or repellent time (time to first bite) was determined for each chemical.

The relative effectiveness of the test material was

Table 2.—Compounds repellent to *Aëdes aegypti* for 3 to 5 hours, showing longer (+) or shorter (−) repellent time as compared with dimethyl phthalate.

Compound	Chemical Class	*Aëdes aegypti*		*Anopheles quadrimaculatus*	
		Unpaired Tests	Paired Tests	Unpaired Tests	Paired Tests
Acetic acid, 1,3-cyclohexandiol diester	IV	−	−	−	−
Acetic acid, 2,2′-thiodiethanol diester	X-a	−	−	−	−
Acetoacetic acid, butyldiethylene glycol ether ester	IV	−		−	
Acetophenone glycerol	V	−	+	−	−
1-Acetoxycyclopentanecarboxylic acid, tetrahydrofurfuryl ester	IV	+	+	−	−
β-Acetoxy-α-hydroxy-isobutyric acid, isoamyl ester	IV	+	−	−	−
β-Acetoxy-α-hydroxy-isobutyric acid, cyclohexyl ester	IV	+	+	−	−
o-Acetylbenzoic acid, methyl ester	IV	−	+	−	−
Acetylsalicylic acid, ethyl ester	IV	−	+	−	−
N-Acetyl-1,2,3,4-tetrahydroquinoline	VIII-a	+	+	−	−
Alkylbenzyl ethers of ethylene glycol	V	+	+	−	−
N-Allyl-3-methyl-1,2,3,6-tetrahydrophthalimide	VIII-a	−	−	−	−
N-Allyl-4-methyl-1,2,3,6-tetrahydrophthalimide	VIII-a	+	+	−	−
N-Allyl-1,2,3,6-tetrahydrophthalimide	VIII-a	+	+	−	−
N-iso-Amyl acetanilide	VIII-a	+	−	−	+
N-*n*-Amyl propionanilide	VIII-a	+	−	−	−
Anisic acid, iso-propyl ester	IV	−	−	−	−
Anthranilic acid, ethyl ester	VIII-b	−		−	
Anthranilic acid, methyl ester	VIII-b	−	−	−	+
Anthranilic acid, *n*-propyl ester	VIII-b	+	+	−	−
Anthranilic acid, iso-propyl ester	VIII-b	−	+	−	+
Benzyl ethylene glycol monoether	V	−	−	−	−
N-Benzylglycine, butyl ester	VIII-b	+	+	−	−
2-Benzylpyridine	VIII-b	−	−	−	−
Bicyclo-(2.2.1)heptene-2,3-dicarboxylic acid, diethyl ester	IV	−	+	−	−
cis-Bicyclo-(2.2.1)heptene-2,3-dicarboxylic acid, dimethyl ester	IV	−	+	−	−
2-(4-Bromophenyl)ethanol	IX	−	+	−	−
p-Butoxybenzaldehyde	III	−	−	−	−
p-sec-Butoxybenzyl alcohol	V	−	−	−	−
N-β-Butoxyethoxyacetylcarbamic acid, butyl ester	VIII-a	−	−	−	−
N-*n*-Butylacetanilide	VIII-a	+	−	−	+
N-*n*-Butyl formanilide	VIII-a	−	+	−	−
N-*n*-Butyl hexahydrophthalimide	VIII-a	+	+	−	−
N-iso-Butyl-4-methylhexahydrophthalimide	VIII-a	+	−	−	
N-iso-Butyl phenethoxyacetamide	VIII-a	−	−	−	−
2-(4-*sec*-Butylphenoxy)ethanol	V	−		−	
N-*sec*-Butyl phthalimide	VIII-a	−	+	−	−
N-Butyl-N-(2-propionoxyethyl) propionamide	VIII-a	−	−	−	−
N-Butyl-1,2,3,6-tetrahydrophthalimide	VIII-a	+	+	−	−
N-*sec*-Butyl-1,2,3,6-tetrahydrophthalimide	VIII-a	+	−	−	−
Butyraldehyde, glycol ester (or hemiacetal of ethylene glycol and butyraldehyde)	V	−		−	
Butyric acid, 1,3-cyclohexanediol monoester	IV	+	+	−	−
Butyric acid, 2-cyclohexanonyl ester	IV	−	−	−	−
n-Butyric acid, 2-ethyl-3-hydroxyhexyl ester	IV	+	−	−	−
n-Butyric acid, 3-phenylpropyl ester	IV	−	−	−	−
n-Butyric acid, 1,2,3,4-tetrahydro-2-naphthyl ester	IV	−	−	−	−
n-Caproic acid, 2-hydroxyethyl ester	IV	−		−	
Caproic acid, 3-hydroxypropyl ester	IV	−	+	−	−
Caproic acid, 1,2-propanediol monoester	IV	−	+	−	−
n-Caproic acid, tetrahydrofurfuryl ester	IV	−	+	−	−
Caprylic anhydride	II	+	+	−	−
α-Chloracetic acid, 2-methyl-2-nitropropyl ester	VIII-d	−	−	+	+
2-(4-Chlorophenoxy)ethanol	IX	+	+	−	−
2-(4-Chlorophenyl)ethanol	IX	+	+	−	−
β-Chloropropionic acid, tetrahydrofurfuryl ester	IX	−	+	−	−
Cinnamic acid, allyl ester	IV	−		−	−
Cinnamic acid, ethyl ester	IV	−	−	−	−
Cinnamic acid, 2-methallyl ester	IV	−	+	−	−
Cinnamic acid, iso-propyl ester	IV	−	+	−	+

Table 2.—(Continued)

COMPOUND	CHEMICAL CLASS	*Aëdes aegypti*		*Anopheles quadrimaculatus*	
		Unpaired Tests	Paired Tests	Unpaired Tests	Paired Tests
Citric acid, tri-*n*-propyl ester	IV	−	−	−	−
Coconut laurin	XI	−	−	−	−
α-Cyanoacetic acid, cyclohexyl ester	VIII-c	−	−	+	+
α-Cyanoacetic acid, 3-methylcyclohexyl ester	VIII-c	−	−	−	−
α-Cyanoacetic acid, 4-methylcyclohexyl ester	VIII-c	−	−	−	−
α-Cyano-α-cyclohexylacetic acid, ethyl ester	VIII-c	−		−	
2-(β-Cyanoethyl)-2-ethylhexanal	VIII-c	+	+	−	−
1-(Cyclohexane-2-ol)butanol	VII	−		−	
Cyclohexan-1-o1-1-carboxylic acid, iso-amyl ester	IV	−		−	
Cyclohexan-1-o1-1-carboxylic acid, cyclohexyl ester	IV	+	−	−	−
Cyclohexan-1-o1-1-carboxylic acid, cyclopentyl ester	IV	−	+	−	−
Cyclohexanone glyceryl acetal	V	−	−	−	+
2-Cyclohexenylcyclohexanol	VII	+	−	−	−
N-Cyclohexyl butoxyacetamide (*Indimide*)	VIII-a	−	−	−	−
Cyclohexyl dipropylene glycol monoether	V	−	−	−	−
Cyclopentan-1-o1-1-carboxylic acid, cyclohexyl ester	IV	+	+	−	−
Cyclopentan-1-o1-1-carboxylic acid, cyclopentyl ester	IV	−	−	−	−
1-Cyclopentenylmalonic acid, diethyl ester	IV	−	−	−	−
Decanediol-2,4	VII	−	+	−	−
N,N-Diamyl acetamide	VIII-a	+	+	+	−
N,N-Di-iso-amyl acetamide	VIII-a	+	+	+	−
Dibenzyl ether	V	−	−	−	−
N,N-Dibutyl-N′-4-oxacyclopentamethylene-sulfamide	VIII-a	−		−	
N,N-Di-iso-butylsuccinamic acid, methyl ester	VIII-a	−		−	
Dicarbethoxyurethane	VIII-a	−	−	−	−
Dicyclopentyl alcohol	VII	+	−	−	−
N,N-Diethyladipamic acid, ethyl ester	VIII-a	+	+	−	−
β-Diethylaminocrotonic acid, methyl ester	VIII-b	+	−	+	+
N,N-Diethylbenzamide	VIII-a	−		−	
N,N-Diethyl alpha-cyclohexoxyacetamide	VIII-a	+	+	−	−
N,N-Diethyl-N′-cyclopentamethylene-sulfamide	VIII-a	−	+	−	−
N,N-Diethylmaleamic (fumaramic?) acid, ethyl ester	VIII-a	+	+	−	−
N,N-Diethyl-4-methyl-1-piperidine-sulfonamide	VIII-a	+		−	
N,N-Diethylsuccinamic acid, ethyl ester	VIII-a	−	−	−	−
N,N-Diethylsuccinamic acid, iso-propyl ester	VIII-a	+	+	−	−
N,N-Diethyl undecylenamide	VIII-a	−	+	−	−
2,4-Dimethyl-3,5-heptanediol	VII	−	−	−	−
3,4-Dimethyl-2,4-hexanediol	VII	−	−	−	−
2,6-Dimethyl-3-(2-hydroxypropoxymethyl)tetrahydropyran	V	+			
2-(2′-5-Dimethylphenyl)cyclohexanol (trans)	VII	−	+	−	−
2,2-Dimethyl-5-phenyl-1,3-dioxolan-4-one	V	+	−	−	−
α, β-Dimethyl-β-phenylglycidic acid, methyl ester	IV	+	−	−	−
α, β-Dimethyl-β-phenylglycidic acid, propyl ester	IV	+	−	−	−
2,6-Dimethyl-3-iso-propyl-4-heptynediol-3,6	VII	+	+	−	−
Dimethyl phthalate (see phthalic acid, dimethyl ester)					
2,3-Dimethyl-1,2,3,6-tetrahydrobenzaldehyde oxime	VIII-e	−	−	−	−
5,8-Dimethyl-1-tetralone	VI	+	+	−	−
Di-(3-phenylpropyl) ether	V	−		−	
Dipropylene glycol 3,3,5-trimethyl cyclohexyl monoether	V	−	+	−	−
N,N-Dipropylglutaramic acid, ethyl ester	VIII-a	+	−	−	−
N,N-Di-iso-propylglutaramic acid, ethyl ester	VIII-a	+	+	−	−
N,N-Dipropylglutaramic acid, methyl ester	VIII-a	−	+	−	−
N,N-Di-iso-propylglutaramic acid, methyl ester	VIII-a	+	+	−	−
N,N-Di-iso-propylglutaramic acid, propy ester	VIII-a	+	+	−	+
N,N-Di-iso-propyl-1-hydroxycyclohexaneacetamide	VIII-a	+	+	−	−
N,N-Dipropyl-3-hydroxy-3-methyl valeramide	VIII-a	+	+	−	−
N,N-Dipropyl levulinamide	VIII-a	−	+	−	−
N,N-Di-iso-propyl levulinamide	VIII-a	−	−	−	−
N,N-Di-iso-propylsuccinamic acid, *sec*-butyl ester	VIII-a	+	+	−	+
N,N-Dipropylsuccinamic acid, ethyl ester	VIII-a	−	+	−	−
N,N-Di-*n*-propylsuccinamic acid, *n*-propyl ester	VIII-a	−	+	−	−
Di-*n*-propyl sulfone	X-a	−	−	−	−

Table 2.—(Continued)

Compound	Chemical Class	*Aëdes aegypti*		*Anopheles quadrimaculatus*	
		Unpaired Tests	Paired Tests	Unpaired Tests	Paired Tests
2,5-Endomethylene-6-methylhexahydrobenzyl ethylene glycol ether	V	−		−	
p-Ethoxyacetophenone	V	−	−	−	−
o-Ethoxybenzoic acid, methyl ester	IV	−	−	+	−
p-Ethoxybenzyl alcohol	V	−	−	+	−
p-Ethoxyphenethyl alcohol	V	+	+	−	−
α-2-Ethylbutyl glyceryl ether	V	+	+	−	−
2-Ethylbutyraldehyde glyceryl acetal	V	−		−	
N-Ethyl-N-(2-butyroxyethyl) butyramide	VIII-a	−	−	−	−
2-Ethyl-*n*-caproic acid	II	−	−	−	−
Ethylene glycol ether of pinene (DHS Activator)	V	−	−	−	−
N-Ethyl formanilide	VIII-a	−	−	−	−
5-Ethyl-2,4-heptanediol	VII	+	−	−	−
3-Ethylhexanediol-2,4	VII	−	+	−	−
2-Ethylhexyl diethylene glycol monoether	V	+	+	−	−
2-Ethylhexyl dipropylene glycol monoether	V	−			
α-2-Ethylhexyl glyceryl ether	V	+	+	−	−
6-Ethyl-2-methyl-4-oxo-2-cyclohexene-1-carboxylic acid, ethyl ester	IV	−	+	−	−
3-Ethyloctanediol-2,4	VII	+	+	−	−
N-Ethyl-N-phenyl-iso-butyramide	VIII-a	−		−	
2-(x-Ethylphenyl)ethanol	VII	−	−	−	+
N-Ethyl-N-phenyl ethanolamine	VIII-b	+	+	−	−
β-Ethyl-β-phenylglycidic acid, methyl ester	IV	−	−	−	−
1-Ethyl-1,2,3,4-tetrahydro-2-naphthol	VII	+	+	−	−
2-Ethynyl-cis-2-decalol	VII	−	−	−	−
Furfurylideneacetic acid, *sec*-butyl ester	IV	−	−	−	−
Furfurylideneacetic acid, ethylene glycol methyl ether ester	IV	+	+	−	−
Furylacyrlic acid, ethylene glycol ethyl ether ester	IV	−	−	−	−
Furylacrylic acid, methallyl ester	IV	−	−	−	−
Geranic acid (3,7-dimethyloctadiene-2,6-oic acid)	II	+	+	−	−
Glycerol-α, gamma-di-iso-amyl ether	V	+	−	−	−
Glycerol furfural	V	+	−	−	−
Heptylic acid, 1,5-pentanediol monoester	IV	+	+	−	−
Hexahydrophthalic acid, diethyl ester (cis)	IV	−	−	−	−
Hexahydrophthalic acid, diethyl ester (trans)	IV	−	−	−	−
Hexoic acid, 2-cyclohexanonyl ester	IV	−	+	−	−
n-Hexyl diethylene glycol monoether	V	−		−	
n-Hexyl glyceryl ether	V	−	−	−	−
o-*n*-Hexyloxybenzaldehyde	III	−	+	−	−
α-Hydroxy-iso-butyric acid, benzyl ester	IV	−	−	−	+
α-Hydroxy-iso-butyric acid, bornyl ester	IV	−	+	−	−
α-Hydroxy-iso-butyric acid, phenylpropyl ester	IV	+	+	−	−
2-Hydroxycaprylic acid, *n*-butyl ester	IV	−	−	−	−
Hydroxycitronellal (2,6-dimethyloctanol-2-al-8)	III	+	+	−	−
Hydroxycitronellal dimethyl acetal (8,8-dimethoxy-2,6-dimethyloctanol-2)	V	−	+	−	−
1-Hydroxycyclohexaneacetic acid, iso-amyl ester	IV	−	−	−	−
1-Hydroxycyclohexaneacetic acid, cyclopentyl ester	IV	+	+	−	−
1-Hydroxycyclohexaneacetic acid, *n*-butyl ester	IV	+	−	−	−
1-Hydroxycyclohexaneacetic acid, cyclopentyl ester	IV	+	+	−	−
1-Hydroxycyclohexaneacetic acid, ethyl ester	IV	−	−	−	−
1-Hydroxycyclohexaneacetic acid, *n*-propyl ester	IV	+	−	−	−
1-Hydroxycyclohexanecarboxylic acid, acetonyl ester	IV	+	+	−	−
1-Hydroxycyclohexanecarboxylic acid, 2-ethoxyethyl ester	IV	−	+	−	−
2-Hydroxy-1-cyclohexenylacetic acid and 2-hydroxy-1-cyclohexylidene acetic acid, lactones of	IV	+	+	+	−
1-Hydroxycyclopentanecarboxylic acid, 2-butoxyethyl ester	IV	+	+	−	−
6-Hydroxy-5-dodecanone	VI	−	−	−	−
1-Hydroxymethylethynyl-1-cyclohexanol (non-crystalline portion)	VII	−	−	−	−
2-Ketocyclohexylglyoxalic acid, ethyl ester	IV	+	+	−	−

Table 2.—(Continued)

Compound	Chemical Class	*Aëdes aegypti*		*Anopheles quadrimaculatus*	
		Unpaired Tests	Paired Tests	Unpaired Tests	Paired Tests
Lactic acid, 82%	II	+		−	
dl-Malic acid, di-*n*-butyl ester	IV	+	−	−	−
Mandelic acid, butyl ester	IV	+	+	−	−
Mandelic acid, iso-butyl ester	IV	+	+	−	−
Mandelic acid, ethyl ester	IV	+	+	−	−
Mandelic acid, *n*-hexyl ester	IV	+	+	−	−
Mandelic acid, iso-propyl ester	IV	+	+	−	−
Methallyl β-benzyloxyethyl ether	V	−	−	−	−
Methallyl β-phenoxyethyl ether	V	−	−	−	−
o-Methoxybenzyl alcohol	V	+	−	−	−
p-Methoxybenzyl alcohol	V	−	+	−	−
1-Methoxy-2-hydroxyindan	V	−	+	−	−
4-Methoxymethyl-2-methyl-1,3-dioxolane-2-propionic acid, ethyl ester	IV	−	+	−	−
1-(*p*-Methoxyphenyl)ethanol	V	+	−	−	−
1-(*p*-Methoxyphenyl)-2-methyl-1,3-propandiol methylene ether	V	−	−	−	−
3-(*p*-Methoxyphenyl)-1-propanol	V	−	+	−	−
4-Methoxyvalerophenone	V	−	−	−	−
Methyl amyl α-glyceryl ether	V	+	+	−	−
α-Methylbenzyl ethylene glycol monoether	V	+	+	−	+
α-Methylbenzyl propylene glycol monoether	V	−		−	
N-Methyl *n*-butyranilide	VIII-a	−	+	−	−
x-Methylcinnamyl alcohol	VII	−	+	−	−
N-Methyl crotonanilide	VIII-a	+	+	−	−
β-Methyl-α-cyanosuccinic acid, diethyl ester	VIII-c	−	+	−	−
x-Methylcyclohexanone cyanohydrin	VIII-c	+	+	−	−
4-Methylcyclohexanone oxime	VIII-e	−	−	−	−
1-Methyl-2,3-dicarboxyethyl cyclopropene	IV	−	−	−	−
8-Methyl-1,5-dioxaspiro(5.5) hendecane-3-ol	V	−	+	−	−
2-Methyl-1,3-dioxolane-2-acetic acid, cyclohexyl ester	IV	−	+	−	−
3,4-Methylenedioxybenzyl *n*-propyl ether	V	−		−	
α-Methylepoxycyclohexylidene acetic acid, allyl ester	IV	+	−	+	+
6-Methyl-2,4-heptanediol	VII	−	+	−	+
3-Methyl-2,4-hexanediol	VII	−	−	−	−
5-Methyl-2,4-hexanediol (mixture of stereoisomers)	VII	−	−	−	−
3-Methyl-4-methoxyacetophenone	V	+	−	−	−
5-Methyl-5-nitro-2-iso-propyl-metadioxane	VIII-d	−	−	−	−
4-Methyl-3,5-nonanediol	VII	−	+	−	−
2-Methyl-4,6-octanediol	VII	−		−	
7-Methyl-2,4-octanediol	VII	+	+	−	+
α-Methylol isobutyrophenone	VI	+	+	−	−
4-Methyl-2-pentenoic acid, ethyl ester	IV	+		−	
m-Methylphenethyl alcohol	VII	−	+	−	+
α-Methyl-β-phenylglycidic acid, allyl ester	IV	−	−	−	−
β-Methyl-β-phenylglycidic acid, allyl ester	IV	+	+	−	−
α-Methyl-β-phenylglycidic acid, methallyl ester	IV	−	−	−	−
β-Methyl-β-phenylglycidic acid, methallyl ester	IV	+	−	−	−
α-Methyl-β-phenylglycidic acid, methyl ester	IV	−	−	−	−
4-Morpholineacetic acid, butyl ester	VIII-b	−	−	−	−
4-Morpholineacetic acid, isobornyl ester	VIII-b	+	−	−	−
1-Naphthonitrile	VIII-c	−	−	−	−
Nicotyrine	VIII-b	+	−	−	+
2-Nitro-2-methyl-1,3-propanediol butyraldehyde acetal	VIII-d	−	−	−	−
2-Nitro-2-methyl-1,3-propanediol crotonaldehyde acetal	VIII-d	+	−	−	−
3-Nitrophthalimide	VIII-a	+		−	
2,4-Nonanediol	VII	−	+	−	+
5-Nonanone oxime	VIII-e	−	−	−	−
1,2-Octanediol	VII	−	+	−	+
2,3-Octanediol	VII	−	−	−	−
2,4-Octanediol	VII	−	+	−	−
N-*n*-Octylsuccinimide	VIII-a	+		−	
α-Oximino-iso-caproic acid, ethyl ester	VIII-e	−	+	−	−
2-Oxycyclopentanecarboxylic acid, cyclopentyl ester	IV	−	+	−	−
Pelargonic acid	II	+	+	−	−

Table 2.—(Continued)

Compound	Chemical Class	*Aëdes aegypti*		*Anopheles quadrimaculatus*	
		Unpaired Tests	Paired Tests	Unpaired Tests	Paired Tests
Pentaerythritol dipropional	V	−	−	−	−
N,N-Pentamethyleneglycine, cyclohexyl ester	VIII-b	+	−	−	−
N,N-Pentamethylenemaleamic (fumaramic?) acid, ethyl ester	VIII-a	+	−	−	−
N,N-Pentamethylenesuccinamic acid, *n*-propyl ester	VIII-a	−	−	−	
N,N-Pentamethylenesuccinamic acid, iso-propyl ester	VIII-a	−	+	−	−
p-iso-Pentoxybenzyl alcohol	V	−	+	−	−
Phenylacetic acid, β-chlorallyl ester	IX	−		−	
ε-Phenylamyl alcohol	VII	−	−	−	−
Phenyl-iso-butyl carbinol	VII	−	−	−	+
Phenyl ethylene glycol monoether	V	−	+	−	−
β-Phenylethyl phenol	VII	−	+	−	−
1-Phenyl-1-hexene-5-one	VI	−	−	−	−
β-Phenyl-β-hydroxy-butyric acid, ethyl ester	IV	−	−	−	−
β-Phenyl-β-hydroxypropionic acid, *n*-butyl ester	IV	−	−	−	−
β-Phenyl-β-hydroxypropionic acid, ethyl ester	IV	+	+	−	−
β-Phenyl-β-hydroxypropionic acid, methyl ester	IV	+	+	−	−
β-Phenyl-β-hydroxypropionic acid, *n*-propyl ester	IV	+	+	−	−
1-Phenyl-3-methylallyl alcohol	VII	−	−	−	−
1-Phenyl-4-pentanone	VI	−		−	
1-Phenyl-2-propoxy ethanol	V	−	+	−	−
Phosphoric acid, tributyl ester	X-b	−		−	
Phthalic acid, dimethyl ester	IV	−		−	
Pivalic acid, 1,5-pentanediol diester	IV	−	−	−	−
Propionic acid, 1,3-cyclohexandiol monoester	IV	+	+	−	−
Propionic acid, 1,6-hexanediol diester	IV	−	+	−	−
Propionic acid, *p*-methoxybenzyl ester	IV	−	−	−	−
Propionic acid, 1,5-pentanediol monoester	IV	−	−	−	+
Propionic acid, 2-phenyl-2-hydroxyethyl ester	IV	−	+	−	−
Propionylsalicylic acid, methyl ester	IV	−	−	−	+
N-Propionyl-1,2,3,4-tetrahydroquinaldine	VIII-a	−	+	−	−
p-*n*-Propoxybenzaldehyde	III	−	−	−	+
p-iso-Propoxybenzaldehyde	III	−	−	−	−
p-*n*-Propoxybenzyl alcohol	V	−	+	−	−
p-iso-Propoxyphenethyl alcohol	V	−	+	−	−
N-*n*-Propyl hexahydrophthalimide	VIII-a	+	+	−	−
2-iso-Propyl-5-methyl-1,3-hexanediol	VII	−	+	−	−
2(*p*-*n*-Propylphenyl)ethanol	VII	+	−	−	−
2(*p*-iso-Propylphenyl)ethanol	VII	−	+	−	−
1-(*p*-iso-Propylphenyl)-3-methyl-2-butanol	VII	−	−	−	−
N-*n*-Propyl propionanilide	VIII-a	+	−	−	−
Pyrogallol dimethyl ether	V	−	+	−	+
1-Pyrroleacetic acid, cyclopentyl ester	VIII-b	−	−	−	−
Tartaric acid, di-iso-propyl ester	IV	+	+	−	−
Terpinyl triethylene glycol ether	V	+	+	−	−
α-Tetrahydrofurfuryl benzyl ether	V	−		−	
β-(1,2,3,4-Tetrahydro-5-naphthyl) ethanol	VII	−	−	−	−
Tiglic acid, phenethyl ester	IV	−	−	−	−
2-(*m*-Tolyl)cyclohexanol (trans)	VII	+	+	−	−
β-*o*-Tolyl ethanol	VII	+	−	−	+
Tri(dimethylaminomethyl)phenol	VIII-b	−	−	−	−
Tri(ethylaminomethyl)phenol	VIII-b	−	−	+	−
2,6,6-Trimethyl-2,3-bicyclo(3.1.1)-heptanediol	VII	+		−	
3,3,5-Trimethyl cyclohexyl dipropylene glycol monoether	V	−	−	−	−
3,3,5-Trimethylcyclohexyl propylene glycol ether	V	−	−	−	−
2,4,4-Trimethyl-3,5-heptanediol	VII	+	+	−	−
3,3,5-Trimethyl-2,4-hexanediol	VII	+	+	−	−
3,6,8-Trimethyl-4-nonynediol-3,6	VII	−	+	−	−
2,5,7-Trimethyl-3-octynediol-2,5	VII	+	+	−	−
dl-Tropic acid, ethyl ester	IV	+		−	
Undecalactone	IV	−		−	
Undecylenic acid (10-undecenoic acid) (pure)	II	−	+	−	−
Wood distillate (66 fraction) 2-hydroxyethyl ether[1]	XII	−	+	−	−
Wood distillate (68 fraction) 2-hydroxyethyl ether[1]	XII	+		−	

[1] Received from commercial source; exact composition not disclosed.

Table 3.—Percentage distribution of the compounds listed in tables 1 and 2 according to chemical class.[1]

CLASS AND TYPE OF COMPOUND	COMPOUNDS EFFECTIVE FOR	
	5 Hours or More	3 to 5 Hours
I Hydrocarbons	0	0
II Acids and anhydrides	6.8	1.9
III Aldehydes	1.7	1.7
IV Esters, lactones	16.9	30.4
V Ethers, acetals	10.2	17.8
VI Ketones	0	1.7
VII Alcohols (including phenols)	16.9	14.2
VIII Nitrogen compounds		
a. Amides, imides	35.6	18.5
b. Amines	1.7	4.9
c. Nitriles	1.7	2.6
d. Nitro compounds	3.4	1.3
e. Any other (azo, azoxy, hydrazo, nitroso, thiocyanates, oximes, etc.)	1.7	1.3
IX Halides	3.4	1.7
X a. Sulfur compounds	0	0.6
b. Phosphorus compounds	0	0.3
XI Natural products	0	0.3
XII Materials of unknown composition	0	0.6
Total	59	303

[1] The classes follow an arrangement by S. Melamed, W. J. Shenk, Jr., N. L. Drake, and S. A. Hall, in 1944 for a special O.S.R.D. report (unpublished).

determined by dividing its repellent time with that of dimethyl phthalate. This ratio multiplied by 100 is called the repellent ratio.

RESULTS.—Data are given in table 1 for the 59 materials that were effective against *Aëdes aegypti* for 5 or more hours. The chemicals are listed alphabetically and the chemical class to which each belongs is indicated by a number (see table 3). Although the average protection time with dimethyl phthalate was shorter than that for any of the compounds listed in table 1, 10 of the materials in paired tests were indicated to be less effective than dimethyl phthalate, as shown by the repellent ratio of less than 100. Twenty-five were superior to 2-ethyl-1,3-hexanediol (average protection 331 minutes), which is the most effective of the standard repellents for *A. aegypti*. N-*n*-Amyl acetanilide, 2,5-endomethylene-6-methyl-hexahydrobenzyl diethylene glycol ether, 2-nitro-2-ethyl-1,3-propanediol crotonaldehyde acetal, 2-phenylcyclohexanol, N-*n*-propyl-1,2,3,6-tetrahydrophthalimide, and 1,2,3,4-tetrahydro-2-naphthol were effective for more than 6 hours.

Against *Anopheles quadrimaculatus* in unpaired tests only N-(*n*-amyl) succinimide, 2,5-endomethylene-6-methylhexahydrobenzyl diethylene glycol ether, 1-phenyl-cyclohexene-2-ol-1, and *n*-undecylenic acid were more effective than dimethyl phthalate, which is the most effective of the standard repellents against this species. In paired tests, 3 of 44 compounds were indicated, by ratios of more than 100, to be more effective than dimethyl phthalate, but the average protection times were shorter than the standard.

The average repellent times for dimethyl phthalate in 202 paired tests with *Aëdes aegypti*, on which the ratios are based, ranged from 171 to 442 minutes, and in 216 paired tests with *Anopheles quadrimaculatus*, 46 to 385 minutes. The arithmetic averages of these group means were, respectively, 285 ± 8.8 and 152 ± 15.2 minutes.

The 303 materials listed in table 2 were effective against *Aëdes aegypti* for 3 to 5 hours. In the unpaired tests they all gave a shorter protection time against this species than 2-ethyl-1,3-hexanediol, but 117 gave a longer protection time than dimethyl phthalate. Of the 106 materials included in the paired tests, 71 were also shown by the repellent ratio to be superior to dimethyl phthalate.

Against *Anopheles quadrimaculatus* only 18 materials had an average protection time greater than dimethyl phthalate in unpaired tests and only 7 of these were also shown superior by the high ratios in paired tests.

The distribution of the effective compounds among the different chemical classes is given in table 3. The classes containing the highest percentage of the effective materials were esters, nitrogen compounds (chiefly amides and imides), ethers, and alcohols. The nitrogen compounds are of especial interest as they have previously received almost no consideration as repellents.

DISCUSSION.—The techniques for this work were designed to evaluate quickly and roughly large numbers of materials. The main objective was to find repellents for military use that were outstandingly superior to those already adopted. In view of the urgency of the project the more time-consuming methods that are necessary to obtain precise data were not used. The repellent time, which is used as the criterion for comparison, is only an index figure, as the exposures were made only every 20 or 30 minutes.

To illustrate the extreme variability that may occur in a series of tests, the complete data are shown in table 4 for two compounds showing nearly equal repellent times for each test species but quite diverse repellent ratios.

Table 4.—Complete repellent data for citronellic acid and 2-(beta-cyano-ethyl)-2-ethylbutyraldehyde.

COMPOUND AND SPECIES	UNPAIRED TESTS		PAIRED TESTS			
				Minutes' Protection		
	Number	Minutes' Protection	Number	Compound	Dimethyl phthalate	Per Cent Ratio
Citronellic acid:						
Aëdes aegypti	4	303 ± 66	4	303 ± 66	317 ± 16	96
Anopheles quadrimaculatus	6	87 ± 20	4	116 ± 8	199 ± 47	58
2-(β-Cyanoethyl)-2-ethylbutyraldehyde:						
Aëdes aegypti	12	302 ± 47	4	354 ± 33	203 ± 32	174
Anopheles quadrimaculatus	12	93 ± 28	4	102 ± 11	67 ± 19	152

The highest repellent ratio obtained with any compound was 260, obtained in two tests with N-ethyl-N-phenyl ethanolamine. Additional tests would probably show a lower ratio. The large figure was the result of an average of 117 minutes' protection for dimethyl phthalate, which is 135 minutes less than the over-all average. The average of 305 minutes for the paired chemical is only 7 minutes above the average for 20 unpaired tests. On the other hand, the ratio of 68 for 4 paired tests with the *sec*-butyl ester of N,N-dipropyl-succinamic acid is the result of an average of 336 minutes for dimethyl phthalate, which is 84 minutes longer than the average for this material. Furthermore, the paired material gave an average of 230 minutes, or 88 minutes less than the average of all tests. At least when the figure represents a large series of tests, the average protection time is likely the best estimate of repellency.

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Insect Pests of Alfalfa in North Carolina

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Frequently during late summer in North Caroline, alfalfa is unthrifty, short and distinctly yellow in color. Mineral deficiencies, diseases, or lack of moisture may be responsible for such a condition; observations during the past several years indicate that harmful insects are often the cause.

Numerous insect collections made in different fields in Wake County during the fall of 1947 showed that a number of insects were feeding on the alfalfa. The poor, unthrifty, fields examined usually had a high population of at least three of the more common insects found on alfalfa, while green thrifty fields were relatively free of these pests. The insects most commonly found were the three-cornered alfalfa hopper, *Stictocephala festina* (Say), the potato leaf-hopper, *Empoasca fabae* (Harr.), plant bugs, *Lygus* spp., the spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber, and the pea aphid, *Macrosiphum pisi* (Kltb.). In addition, grasshoppers as well as several species of caterpillars were found. The caterpillars usually were the green clover worm and the fall armyworm, as well as other species that were not identified at the time collections were made. Some fields were completely destroyed by fall armyworms during 1947 and 1948. All of the collections reported here, however, were made in fields where fall armyworms were not very abundant.

The life cycle of *Stictocephala festina* was described by Wildermuth (1915) more than 30 years ago. Reports of damage caused by this insect since that time have been few. In 1947, it was very abundant in many of the fields examined in Wake County, North Carolina. The type of damage is easily recognized; the nymphs as well as the adults feed by thrusting their beaks into the plant and sucking out the plant juice. Feeding is often in a continuous line forming a ring or girdle around the stem. The latter type of feeding weakens the stem with the usual loss of color and stunting of growth. In several cases most of the stems may yellow or die before they reach a height of 6 inches. Stand losses have been observed on heavily infested areas.

During 1947 a nursery consisting of seventy-six alfalfa strains was severely infested with *Stictocephala festina*. Data on yellowing, percentage girdled stems, and numbers of *S. festina* per plot failed to reveal a strain with any degree of resistance.

In late season stands, where alfalfa was not cut for hay or used for grazing, satisfactory control of this insect has been obtained by dusting with 3 per cent of the gamma isomer of benzene hexachloride or with a combination dust of 3 per cent gamma benzene hexachloride and 5 per cent DDT at the rate of 15 to 20 pounds per acre. Forage treated with these insecticides should not be fed to, or pastured by, dairy animals or animals being finished for slaughter.

Studies of the effects of insects on the vegetative growth of alfalfa by Stitt (1948) indicate that insects materially reduce the growth of alfalfa in Arizona and California during the period of high temperatures from late June to September. A rapid increase in numbers of harmful insects was noted between May 27 and June 30. While no attempt was made to measure the damage caused by the various pests feeding on alfalfa in North Carolina, these insects are undoubtedly important factors in late summer unproductiveness of alfalfa.

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Preliminary Evaluation of Materials as Synergists with Pyrethrum Against the Body Louse[1]

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Tests with synergists[3] for pyrethrum against the body louse, *Pediculus humanus corporis* Deg., have been described by Bushland *et al.* (1944a). In those

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

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[3] The term "synergist" is used here in a broad sense to include compounds that are not insecticidal.

studies, conducted early in the work of the Bureau of Entomology and Plant Quarantine to develop a louse powder for the armed forces, more than 200 compounds were investigated. Their most effective synergist was N-isobutylundecylenamide (*IN-930*), which was used in the MYL powder developed by Bushland *et al.* (1944b). However, they found that many other compounds increase the toxicity of pyrethrum to body lice. It appears that the body louse is very sensitive to synergistic action involving combinations of pyrethrum and other materials, and therefore serves as a good insect for screening compounds for this purpose.

Extensive tests have since been conducted on new materials in search for more effective pyrethrum synergists against lice, and the results are reported in this paper. The body lice used in these tests were taken from a laboratory colony maintained as described by Culpepper (1944).

MATERIALS AND METHODS.—In the selection of materials for testing, special emphasis was given to chemicals related to previously tried and proved synergists, although a great many were chosen without regard to their chemical nature in an effort to detect synergism in new chemical groups. A few of the compounds had previously been tested by other techniques, but were included in this work for the purpose of comparison of method.

For preliminary evaluation of the materials, the beaker test method (Bushland *et al.* 1944b) was used. This method is briefly as follows: Circles of woolen cloth 1.5 inches in diameter were immersed in acetone solutions of the test materials. After drying in the open for about an hour, the impregnated pieces of cloth were placed in 50-ml. beakers and 20 young adult lice were introduced. During the tests the lice were held at 30° C. and approximately 75 per cent relative humidity.

Preliminary tests with the potential synergist were made at 0.25 per cent concentration in combination with 0.025 per cent of pyrethrins (prepared from a 20 per cent concentrate). This concentration of pyrethrins alone usually caused little or no mortality of the lice in 24 hours. Combinations causing at least 80 per cent mortality of lice at this concentration were retested at one-half strength (0.125 per cent of the synergist plus 0.0125 per cent of pyrethrins). Formulas causing similar mortality at this strength were diluted to contain 0.05 per cent of synergist plus 0.005 per cent of pyrethrins. Materials in combination with pyrethrins, which caused at least 50 per cent mortality at this low concentration, were tested alone to determine their individual toxicity to lice. Only a few of these compounds indicated any toxicity to lice.

Final evaluations to determine the lasting properties of the various materials were made by testing them by the arm-and-leg method described by Bushland *et al.* (1944b). This test consisted of treating the inner surface of balbriggan-cloth sleeves with 3 grams (per sleeve) of a powder containing 2 per cent of the synergist plus 0.2 per cent of pyrethrins. The treated sleeves were placed on the arms and legs of research subjects, 25 lice were introduced into each

Table 1.—Per cent mortality of lice subjected to different strengths of the better synergists, alone and in combination with pyrethrum.

MATERIAL	0.25 PER CENT		0.125 PER CENT		0.05 PER CENT	
	With 0.025 Per Cent of Pyrethrins	Alone	With 0.0125 Per Cent of Pyrethrins	Alone	With 0.005 Per Cent of Pyrethrins	Alone
N-isoButylundecylenamide (*IN-930*)	100	0	100	0	58	0
d-Camphoric acid, diallyl ester	100	0	100	0	90	0
cis-3,6-Endomethylene-1,2,3,6-tetrahydrophthalic acid, di(2-ethylhexyl) ester	85	0	80	0	50	0
Hexahydrophthalic acid, di-*n*-butyl ester	100	40	100	0	50	0
Hexahydrophthalic acid, diethyl ester	100	100	100	0	50	0
Hexahydrophthalic acid, di-*n*-propyl ester	100	100	100	90	95	0
Hexahydrophthalic acid, di-iso-propyl ester	100	100	95	0	50	0
Homophthalic acid, di-*n*-propyl ester	100	70	100	0	100	0
Isosafrole	100	50	100	0	50	0
3,4-Methylenedioxycinnamic acid, ethyl ester	100	0	100	0	95	0
1-(3,4-Methylenedioxyphenyl)-1-acetoxybutene-3	100	0	100	0	70	0
α-Methyl-α-phenylcyclohexanone	100	100	100	60	60	0
Phthalic acid, di-*sec*-butyl ester	90	0	95	0	90	0
Phthalic acid, di-iso-propyl ester	100	100	100	0	70	0
Piperonylacetonitrile	100	100	95	0	50	0
Piperonyl butoxide	100	0	100	0	78	0
Piperonyl cyclonene	100	0	100	0	78	0
Piperonylic acid, *n*-amyl ester	100	0	100	0	90	0
Piperonylic acid, *n*-butyl ester	100	60	100	0	65	0
Piperonylic acid, ethyl ester	100	70	100	0	100	0
Piperonylic acid, *n*-propyl ester	100	100	100	0	50	0
Piperonylidenemalonic acid, di-*n*-butyl ester	100	0	95	0	90	0
Piperonylidenemalonic acid, diethyl ester	95	0	95	0	70	0
Pyrethrins (tested alone)	0		0		0	

sleeve, and the openings were sealed with adhesive tape. Mortality records were taken at intervals of 24 hours during the first 4 days, and at 48 hours thereafter or until the treatments failed to cause about 90 per cent mortality of lice.

MATERIALS SHOWING SYNERGISM.—Of the materials tested, 23 significantly increased the toxicity of pyrethrins. The results obtained with these materials, when tested alone and in combination with pyrethrins, are presented in table 1. Twenty materials caused 100 per cent mortality of lice at a concentration of 0.25 per cent in combination with 0.025 per cent of pyrethrins. However, 12 of them proved toxic to lice when tested alone at 0.25 per cent. At 0.125 per cent incombination with 0.0125 per cent of pyrethrins, 17 compounds caused 100 per cent mortality, whereas in the absence of pyrethrins only 2 caused any mortality of lice. At the lowest concentration tested, 0.05 per cent in combination with 0.005 per cent of pyrethrins, all 23 materials caused 50 to 100 per cent mortality of lice, whereas without pyrethrins no mortality occurred. Pyrethrins tested alone at 0.025 per cent caused no mortality of lice.

MATERIALS SHOWING SLIGHT OR QUESTIONABLE SYNERGISM.—There were 90 compounds which showed slight or questionable synergism. These materials have been arranged in alphabetical order in list 1. Most of the materials caused 100 per cent mortality of lice at 0.25 per cent in combination with 0.025 per cent of pyrethrins but not at lower concentrations. In many instances the test material itself may have been largely responsible for the mortality. If the mortality caused by the combination was not clearly greater than that which was anticipated, no further tests were conducted. Since N-isobutyl-undecylenamide had already been shown to increase the toxicity of pyrethrum against the body louse approximately 100 times (Bushland *et al.* 1944a), extensive tests on the materials in list 1 were not considered justifiable.

List 1.—Materials indicating slight or questionable synergism at 0.25 per cent in combination with 0.025 per cent of pyrethrins.

Acetic acid, piperonyl ester
N-Allylphthalimide
1,4-Benzodioxan
cis-Bicyclo-(2,2,1)heptene-2,3-dicarboxylic acid, dibutyl ester
5-Bromosalicylic acid, methyl ester
N-isoButylcapramide
N-isoButyllauramide
N-(*n*-Butyl)-N-phenylacetamide
N-*n*-Butylphthalimide
Butyric acid, piperonyl ester
d-Camphoric acid, dimethyl ester
α-Carbethoxy-α, β-dimethylglutaric acid, diethyl ester
α-Carbethoxy-β-phenylglutaric acid, diethyl ester
Chloroacetic acid, alpha-trichloro-*tert*-butyl ester
4-Chlorocyclohexylbenzene
α-Chloronaphthalene
Cinnamic acid, iso-propyl ester
Cyclohexanecarboxylic acid, cyclohexyl ester
Cyclohexanol-1-carboxylic acid, 2-ethylbutyl ester
N-Cyclohexylbutoxyacetamide
4-Cyclohexylcyclohexanone
2-Cyclohexylidenecyclohexanone
N,N-Diamylacetamide
1,2-Dibromo-1,2-dicarbethoxycyclobutane
α,α'-Dibromo-β, β'-dimethylglutaric acid, diethyl ester
4-(1,2-Dibromoethyl) toluene
α,α'-Dicarbethoxyazelaic acid, diethyl ester
3,4-Dichloronitrobenzene
Diethylamidotetrahydrobenzoic acid, methyl ester
Diethyltrichlorobenzene
Dihydrosafrole
β,β-Dimethylglutaric acid, diethyl ester
3-Ethoxyphthalide
N-Ethyl-N-phenyl-*n*-decanamide
α-Ethyl-β-phenylglycidic acid, allyl ester
x-Ethyl-*x*-tetrachlorobenzene
d-Glutamic acid
Glutaric acid, di-*n*-butyl ester
Glutaric acid, di-iso-butyl ester
Glutaric acid, diethyl ester
Glutaric acid, dimethyl ester
Glutaric acid, di(2-methyl-1-butyl) ester
Glutaric acid, di-*n*-propyl ester
Glutaric acid, di-iso-propyl ester
Glutaric acid, monoethyl ester
Glutaric acid, monopropyl ester
Glutaric anhydride
Glutaronitrile
N-Heptylacetamide
Hexahydrobenzoic acid, 3-butyn-1-yl ester
Hexahydrobenzoic acid, dimethylethynyl carbinyl ester
Hexahydrobenzoic acid, methylethylethynyl carbinyl ester
Hexahydrobenzoic acid, 2-octynyl-1 ester
Hexahydrophthalic acid, diethyl ester (cis)
Hexahydrophthalic acid, dimethyl ester
Homophthalic acid, diethyl ester
Lactamide
Lauryl bromide
cis-*o*-Methoxycinnamic acid, methyl ester
3,4-Methylenedioxy-beta-nitrostyrene
2-(3,4-Methylenedioxyphenyl)-4, 4-diethyl-1, 3-dioxane
N-(3,4-Methylenedioxythiobenzoyl) morpholine
N-(3,4-Methylenedioxythiobenzoyl) piperidine
α-Methyl-α-phenylcyclopentanone
p-Nitrobenzoic acid, methyl ester
α,α,α-3,4-Pentachlorotoluene
Phenylcyclohexanone
tere-Phthalic acid, isobutyl cyclohexyl ester
Phthalic acid, diallyl ester
Phthalic acid, di(*sec*-butyl carbinol) ester
Phthalic acid, di-iso-butyl ester
Phthalic acid, diethyl ester
tere-Phthalic acid, diethyl ester
Phthalic acid, dimethyl ester
Phthalic acid, di-*n*-propyl ester
Phthalic acid, methyl propyl ester
Piperidine piperidyldithiocarbamate
α-1-Piperidyl-α-tolunitrile
Piperine
Piperonyl alcohol
Piperonylic acid, tetrahydrofurfuryl ester
Piperonylmalonic acid, diethyl ester
Propionic acid, 2,3-methylenedioxypropyl ester
Propionic acid, piperonyl ester
Sesamin concentrate
Styrene dibromide
Tetrahydrophthalic acid, di-*n*-butyl ester
Tetrahydrophthalic acid, diethyl ester
Tetrahydrophthalic acid, di-iso-propyl ester

MATERIALS SHOWING NO SYNERGISM.—Approximately 75 per cent (333) of the 446 compounds

tested failed to cause as much as 80 per cent mortality at 0.25 per cent in combination with 0.025 per cent of pyrethrins. These materials have been arranged in alphabetical order in list 2. Quite possibly, if further tests had been conducted, some of the materials in this list would have proved better synergists than some of those included in list 1, since it was not known whether the mortality shown was due to true synergism or to toxicity of the test material. However, the materials did not prove sufficiently promising to warrant further investigation.

List 2.—Materials indicating no synergism at 0.25 per cent in combination with 0.025 per cent of pyrethrins.

Acetamide
Acetic acid, bornyl ester
Acetic acid, cinnamyl ester
Acetic acid, glyceryl triester
Acetoacetanilide
Acetoacet-2,5-dichloroaniline
p-Acetotoluide
α-Acetoxypropionamide
α-Acetoxypropionanilide
α-Acetoxypropionic acid, ethylene glycol di-ester
Acetyl *p*-anisidine
Acetylcitric acid, triethyl ester
Acetylenedicarboxylic acid, di(β-chloroethyl) ester
Acetyl-*o*-phenetidine
Acetyl *p*-phenetidine
Acrylamide
Acrylic acid, cyclohexyl ester
Adipic acid, dicyclohexyl ester
Adipic acid, dimethyl ester
Adipyl morpholide
Allyl 5-ethyl-2-xenyl ether
p-Aminoacetanilide
p-Aminobenzoic acid, methyl ester
N-Amylacetamide
α-(*x*-Amyl)-*x*-(β-phenylethyl)malonic acid, diethyl ester
Anisic acid, ethyl ester
Azelaic acid, di(2-butoxyethyl) ester
Benzamide
Benzanilide
Benzene hexachloride, mixed isomers
Benzilic acid, ethyl ester
m-Benzotoluide
N-Benzylpyromucamide
Bicyclo-(2,2,1)heptene-2,3-dicarboxylic acid, diallyl ester
Bicyclo-(2,2,1)heptene-2,3-dicarboxylic acid, di-β-chloro-ethyl ester
cis-Bicyclo-(2,2,1)heptene-2,3-dicarboxylic acid, dimethyl ester
N-bis (β-acetoxyethyl)-alpha-acetoxypropionamide
3-Bromoacenaphthene
p-Bromoacetanilide
2′-Bromobenzanilide
2-Bromo-4-cyclohexyltoluene
1-Bromonaphthalene
N-*p*-Bromophenylphthalimide
N-Butylacetamide
N-isoButylacetamide
N-*sec*-Butylacetamide
N-Butylbenzamide
N-iso-Butylbenzamide
N-*sec*-Butylbenzamide
N-iso-Butylcapramide
N-Butylcinnamamide
N-iso-Butylcinnamamide
N-*sec*-Butylcinnamamide
N-(*n*-Butyl)-6-cyclohexyl-2-hexenamide
x-*tert*-Butyl-1,2-dichlorobenzene
N-Butyllauramide
N-Butyl-m-nitrobenzamide
N-*sec*-Butyl-m-nitrobenzamide
N-iso-Butylphthalimide
N-iso-Butylpropionamide
N-*sec*-Butylpropionamide
Butyl safrole
N-Butyl-α-toluamide
N-Butyl-*o*-veratramide
iso-Butyraldehyde trimer
Butyranilide
iso-Butyric acid, benzyl ester
n-Butyric acid, *n*-propyl ester
d-Camphoric acid, diethyl ester
Caproic acid
Caproic acid, allyl ester
2-Carbethoxycyclohexanone
α-Carbethoxyglutaric acid, diethyl ester
Carbonic acid, diphenyl ester
α-Carboxysuccinic acid, triethyl ester
Castor oil fatty acids, glycerol-α,α′-dimethyl ether esters
Castor oil fatty acids, tetrahydrofurfuryl esters
Chaulmoogric acid, methyl ester
α-Chloroacetanilide
o-Chloroacetoacetanilide
β-Chlorobutyramide
α-Chloroisobutyramide
2-Chloro-1,4-di-iso-propylbenzene
2-Chloronaphthaline
2′-Chloro-3-nitrobenzanilide
α-Chloropropionamide
Cinnamamide
Cinnamic acid, cinnamyl ester
Cinnamic acid, linalyl ester
2-Cinnamyl-1,3-oxathiolane
Citric acid, triallyl ester
Citric acid, tribenzyl ester
Citric acid, tributyl ester
Citric acid, tri-*n*-hexyl ester
o-Cyanobenzamide
Cyclohexanecarboxylic acid, methyl ester
Cyclohexan-1-ol-1-carboxylic acid, cyclohexyl ester
Cyclohexan-1-ol-1-carboxylic acid, cyclopentyl ester
Cyclohexanol-1-carboxylic acid, 2-hydroxyethyl ester
Cyclohexanol-1-carboxylic acid, 3-hydroxypropyl ester
Cyclohexan-1-ol-1-carboxylic acid, *n*-propyl ester
4-Cyclohexene-1,2-dicarboxylic acid, dimethyl ester
4-Cyclohexene-1,2-dicarboxylic acid, di-2-chloroallyl ester
α-Cyclohexylbutyric acid, propyl ester
Cyclohexyl dipropylene glycol monoether
N-Cyclohexyl-m-nitrobenzamide
Decahydronaphthaline
Diacetyltartaric acid, di-*n*-amyl ester
Dibenzylaminoethanol
1,1-Dibromo-2,2-bis(*p*-bromophenyl)ethane
1,1-Dibromo-2,2-bis(*p*-chlorophenyl)ethane
2,4-Dibromo-α-naphthol
α,β-Dibromo-β-nitroethylbenzene
x,*x*-Dibromotoluene
N,N-Dibutylacetamide

Dibutyl ethylene glycol diphthalate
N,N-Dibutylpropionamide
N,N-Di-*n*-butyltoluenesulfonamide
α,α'-Dicarbethoxyglutaric acid, diethyl ester
o-Dichlorobenzene
p-Dichlorobenzene
x,x-Di-(*x*-chlorobenzyl)chlorobenzene
1,1-Dichloro-2,2-bis(*p*-bromophenyl)ethylene
α,α-Dichlorobutyramide
1,1-Dichloro-2,2-bis(*p*-chlorophenyl)ethane
1,1-Dichloro-2,2-diphenylethylene
2,4'-Dichlorodiphenylmethane
2,4-Dichloro-1-naphthol
1,4-Dichloro-2-nitrobenzene
1,1-Dichloro-1-nitroethane
1,1-Dichloronitropropane
2,4-Dichlorooxanilic acid, ethyl ester
1,3-Di-(*x*-chlorophenyl)-2-methylpropane
α,α-Dichloropropionamide
α,β-Dichloropropionamide
3,4-Dichlorotoluene
Di(*p*-chlorotolyl)trichloroethane
N,N-Dicyclohexyl-*m*-nitrobenzamide
N,N-Diethylacetamide
N,N-Diethylbutyramide
N,N-Diethylpropionamide
N,N-Diethylundecylenamide
2,3-Dihydro-3-phenyl-1,4-phthalazinedione
N,N-Dimethylformamide
N,N-Dimethylmethoxyacetamide
2,4-Dinitrobromobenzene
2,4-Dinitrochlorobenzene
Dinitro-1-trichloro-2,2-bis(*p*-chlorophenyl)ethane
1-(3,4-Dioxymethylenephenyl)-2-methyl-1,3-propandiol methylene ether
N,N-Di-iso-propyl acetamide
N,N-Dipropylpropionamide
N,N-Di-iso-propylpropionamide
Dodecane-1,1,12,12-tetracarboxylic acid, tetraethyl ester
cis-3,6-Endomethylene-1,2,3,6-tetrahydrophthalic acid, di-*n*-hexyl ester
Ethoxymethylenemalonic acid, diethyl ester
N-Ethylacetemide
N-Ethylbanzamide
N-Ethyl-N-phenyl-iso-butyramide
Ethyl phthalyl glycolic acid, methyl ester
Formanilide
Formic acid, methyl ester
p-Formotoluide
Furfurylideneacetic acid, *n*-propyl ester
Heptamethylene bromide
n-Heptylic acid
2-Heptynoic acid
Hexachloroethane
Hexahydrobenzoic acid, ethyl ester
Hexahydrobenzoic acid, 1-ethynylcyclohexyl ester
Hexahydrobenzoic acid, methylisobutylethynyl carbinyl ester
Hexahydrobenzoic acid, 3-octynyl-1-ester
Hexahydrophthalic acid, diallyl ester
Hexahydrophthalic acid, diisoamyl ester
Hexahydrophthalic acid, diethyl ester (trans)
(1-Hexenyl)ethylmalonic acid, diethyl ester
Homophthalic acid, dimethyl ester
Hydratropic aldehyde
p-Hydroxybenzoic acid, benzyl ester
Hydroxycitronellic acid
1-Hydroxycyclohexaneacetic acid, iso-amyl ester
2-Hydroxycyclohexane carboxylic acid, ethyl ester
N-(2-Hydroxyethyl) acetamide
N-β-Hydroxypropyl-3,6-endomethylene-1,2,3,6-tetrahydrophthalimide
N-β-Hydroxypropyl-1,2,3,6-tetrahydrophthalimide
2-Iodo-3-nitrotoluene
Iodosobenzene
m-Iodosonitrobenzene
p-Iodosonitrobenzene
Itaconic acid, diethyl ester
Lactic acid, cyclohexyl ester
Maleic acid, diallyl ester
dl-Malic acid, di-*n*-butyl ester
Mandelic acid, butyl ester
Mandelic acid, methyl ester
4-Methoxycyclohexanone-1
α-Methoxycyclohexylideneacetic acid, methyl ester
β-Methoxypropionic acid, gamma-chloropropyl ester
β-Methyladipic acid, diethyl ester
Methyl alcohol
N-(1-Methylamyl) benzamide
N-Methylbenzamide
Methyl chloroform
p-Methyl-α-methylstyrene dibromide
N-Methyl-*m*-nitrobenzamide
N-Methylphthalimide
Methyl phthalyl glycolic acid, methyl ester
N-Methyl-alpha-toluamide
Myristic acid, chloroethyl ester
Naphthenic acid, butyl ester
Naphthenic acid, ethyl ester
Naphthenic acid, glyceryl ester
Naphthenic acid, glycol ester
Naphthenic acid, pentaerythritol ester
Naphthenc acid, tetrahydrofurfuryl ester
N-(1-Naphthyl) benzanilide
N-2-Naphthylpropionamide
α-Naphthyl thioacetamide
p-Nitroacetanilide
Nitrobenzamide
2'-Nitrobenzanilide
o-Nitrobromobenzene
Octadecyl bromide
o-Phenylbenzanilide
N-(α-Phenylbutyryl) piperidine
N-Phenyl-N-ethylfurylacrylamide
Phosphoric acid, di-(o-xenyl) phenyl ester
Phthalic acid, butyl acetonyl ester
Phthalic acid, butyl hexyl ester
Phthalic acid, *n*-butyl hydrogen ester
Phthalic acid, *sec*-butyl hydrogen ester
Phthalic acid, butyl loralkyl ester
Phthalic acid, cyclohexyl hydrogen ester
Phthalic acid, di-(allyl lactate) ester
Phthalic acid, diamyl ester
Phthalic acid, di-iso-amyl ester
Phthalic acid, dibenzyl ester
Phthalic acid, di-(*o*, *p*-benzylphenyl) ester
Phthalic acid, di-(butoxyethyl) ester
Phthalic acid, dicapryl ester
Phthalic acid, di-beta-chloroethyl ester
Phthalic acid, di-*o*-cresyl ester
Phthalic acid, di-(β'-ethoxy-β-ethoxyethyl) ester
Phthalic acid, di-(β-ethoxyethyl lactate) ester
Phthalic acid, di-2-ethylbutyl ester
Phthalic acid, di-(2-ethylbutyl lactate) ester
Phthalic acid, diethylene glycol hydrogen ester
Phthalic acid, di-2-ethylhexyl ester
Phthalic acid, di-(2-ethylhexyl lactate) ester
Phthalic acid, di-(ethyl lactate) ester

Phthalic acid, diglyceryl ester
Phthalic acid, di-HTP-B22 ester
Phthalic acid, di-HTP-B24 ester
Phthalic acid, dilauryl ester
Phthalic acid, di(methoxyethoxyethyl) ester
Phthalic acid, di-beta-methoxyethyl ester
Phthalic acid, di(methoxymethoxyethyl) ester
Phthalic acid, di-(methyl lactate) ester
Phthalic acid, ethyl acetonyl ester
Phthalic acid, ethyl butanonyl ester
Phthalic acid, ethyl 2-cyclohexanonyl ester
Phthalic acid, ethyl cyclohexyl ester
Phthalic acid, ethyl hydrogen ester
Phthalic acid, ethyl methylcyclohexyl ester
Phthalic acid, *n*-heptyl hydrogen ester
Phthalic acid, *n*-hexyl hydrogen ester
Phthalic acid, 4-hydroxymethyl-2,2-dimethyldioxolane hydrogen ester
Phthalic acid, methyl butyl ester
Phthalic acid, methyl cyclohexyl ester
Phthalic acid, methyl ethyl ester
Phthalic acid, methyl *n*-hexyl ester
Phthalic acid, methyl hydrogen ester
Phthalic acid, methyl *n*-octyl ester
Phthalic acid, *n*-octyl hydrogen ester
Phthalic acid, polymerized glycol ester
Phthalic acid, *n*-propyl cyclohexyl ester
x-Pinenyl-2-phenyl phenol
Piperonal
Piperonal glycerol acetal
1,1,2-Propanetricarboxylic acid, triethyl ester
x-(*n*-Propoxy)salicylic acid, 2-butoxyethyl ester
N-Propylacetamide
N-iso-Propylacetamide
N-iso-Propylacetanilide
N-iso-Propylbenzamide
N-Propylcinnamamide
N-iso-Propylcinnamamide
N-Propyl-*m*-nitrobenzamide
N-iso-Propyl-*m*-nitrobenzamide
N-iso-Propylpropionamide
N-iso-Propyl-α-toluamide
N-iso-Propylundecylenamide
Pyromucoanilide
Ricinoleic acid, β′-ethoxy-β ethoxyethyl ester
Salicylamide
Salicylic acid, menthyl ester
Salicylic acid, β-naphthyl ester
Sebacic acid, di-(beta-chloroethyl lactate) ester
Sebacic acid, dimethallyl ester
Stearic acid, benzyl ester
Stearic acid, butyl ester
Succinic acid, di(allyl lactate) ester
Succinic acid, ditetrahydrofurfuryl ester
Tartaric acid, dibenzyl ester
Tartaric acid, di(2-butoxyethyl) ester
m-Terphenyl
3,6-Tetrahydrophthalic acid, (ethylene glycol benzyl ether) hydrogen ester
Tetrachlorophthalic acid, ethyl hydrogen ester
1,2,3,6-Tetrahydrophthalic acid, monoallyl ester
1,2,3,6-Tetrahydrophthalic acid, monocyclohexyl ester
1,2,3,4-Tetrahydrophthalic acid, monopropyl ester
p-Toluene sulfonomethylamide
N-*o*-Tolylcinnamamide
N-*p*-Tolylcinnamamide
1-Tribromo-2, 2-bis (*p*-bromophenyl) ethane
1-Tribromo-2, 2-bis (*p*-chlorophenyl) ethane
1-Trichloro-2, 2-bis (*p*-bromophenyl) ethane
1-Trichloro-2, 2-bis (*p*-hydroxyphenyl) ethane
1-Trichloro-2, 2-bis (nitrotolyl) ethane
α,α,β-Trichlorobutyramide
α,α,γ-Trichlorobutyramide
1-Trichloro-2-(*p*-chlorophenyl)-2-phenyl ethane
1-Trichloro-2, 2-diphenyl ethane
1-Trichloro-2, 2-di-*p*-tolyl ethane
α,α,β-Trichloropropionamide
α-Trichlorotoluene
Undecylenic acid, methyl ester
N-Xenylacetamide
N-Xenylformamide
N-Xenylpyromucamide
N(2,6-Xylyl) benzamide
N(2,4-Xylyl) formamide
N(2,5-Xylyl) formamide
N(2,6-Xylyl) propionamide

MATERIALS SHOWING MOST LASTING EFFECTS.—In lasting effects, as determined by the arm-and-leg method, six materials were found to compare favorably with N-isobutylundecylenamide. They were the diethyl ester of piperonylidenemalonic acid; the di-*n*-butyl ester of hexahydrophthalic acid; 11 (3,4-methylene-dioxyphenyl)-1-acetoxybutene-3; the di(2-ethylhexyl) ester of cis-3,6-endomethylene-1,2,3,6-tetrahydrophthalic acid; the ethyl ester of 3,4-methylene-dioxycinnamic acid; and isosafrole. Two materials, di-*n*-butyl ester of piperonylidenemalonic acid and piperonyl cyclonene, proved more effective than N-isobutylundecylenamide. The di-*n*-butyl ester of piperonylidenemalonic acid appeared to be a better synergist than piperonyl cyclonene.

In preliminary tests piperonyl butoxide was less effective than piperonyl cyclonene as a synergist. In tests made with the two materials alone (without pyrethrins), piperonyl butoxide proved the more toxic.

SUMMARY.—Of 446 compounds tested for synergistic action with pyrethrum against the body louse, *Pediculus humanus corporis* Deg., the most effective, when tested by the arm-and-leg method, were the di-*n*-butyl ester of piperonylidenemalonic acid, piperonyl cyclonene, and N-isobutylundecylenamide. When tested by the beaker method, 23 definitely increased the toxicity of pyrethrum, and the most effective were the diallyl ester of *d*-camphoric acid; N-isobutylundecylenamide (*IN-930*); the ethyl ester of 3,4-methylenedioxycinnamic acid; the *n*-amyl ester of piperonylic acid; piperonyl cyclonene; 1-(3,4-methylenedioxyphenyl)-1-acetoxybutene-3; and the di-*n*-butyl ester of piperonylidenemalonic acid.

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Habits and Control of the Black Widow Spider

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It is the purpose of this paper to present the results of 8 years' collecting and observation on the habits of the black widow spider, *Latrodectus mactans* Fab., within the limits of the City of New York, and to present a method which effects its control.

During the period from September 1941 to December 1948, 137 black widow spiders have been collected by the author within the city limits. Records of their distribution and web structure have been kept. Since little of this sort of information has been found available in books on medical entomology, it was thought worthy of publication.

The black widow spider, usually abundant in the southern states, has a surprisingly large population in New York. It has taken advantage of city conditions to thrive in the many nesting places inadvertently provided by man.

The typical *Latrodectus* web is found in a flat, dry area. The area is usually barren or only sparsely covered with vegetation. The area must provide some suitable hiding place close to the ground. For example, many webs are encountered under large pieces of building paper or under wooden timbers. The wooden timbers preferred as nesting places are at least 2 feet in one dimension by at least 6 inches in another dimension. Small sticks, splinters, sheets of cardboard, assorted scraps of metal, concrete slabs, brickwork, and other city debris seem to be consistently rejected as housing for the webs. The typical web is placed on the under side of the object affording the hiding place. The hiding place is close to the ground but never in contact with it. There must be gaps and irregular spaces between the hiding place and the earth, in order that both spider and her prey may gain access to the shelter. The web is coarse, asymmetrical, and attached to the supporting surface at random. Although the web is not in contact with the earth, the slack in the webbing loops toward the ground and frequently adheres to bits of sand or small pebbles. Thus when the hiding place is lifted for observation, one sees a typical irregular web with assorted fragments of earth dangling in the strands. The spider may be found in the web, or in some crevice within 4 or 5 inches of the web.

The black widow is usually slow moving when her hiding place is upturned. Frequently she will remain in the web for a number of minutes. When she does retreat, it is only to the lower surface of the same hiding place.

From the above description, it is apparent that the black widow prefers areas littered with city debris. They have been successfully collected in city dumps, rubbish filled vacant lots, railroad yards, demolition and construction sites and in one of the city parks.

The conditions found suitable for nest building indicate considerable discrimination on the part of the spiders. The author has never seen a black widow living on paved areas. A number of abandoned roads in Queens were found covered with apparently suitable rubbish, adjacent lots of vacant land were found harboring many black widows, yet none of the spiders were nesting over the pavement. Asphalt paving may be rejected because of its high heat absorption, yet black widows have been found thriving under black tarred building paper at a temperature of 38.5° C.

Although barren soil is preferred, areas covered with ashes or cinders may be used for living quarters provided the proper hiding places exist. Surfaces of crushed rock, gravel or concrete are abhorred, as are areas planted in grass or permitted to become covered with weeds.

The preference for large, stable hiding places may be circumvented under crowded conditions, or if small hiding places are firmly anchored.

Atypical locations for black widows and their webs have been noted. A few of these are listed below:

Flushing, N. Y. An empty nail keg with burlap sacking along its rim in a vacant lot contained two mature females and one mature male, each in its own web. July 12, 1942.

Corona, N. Y. A hollow concrete tile, partly sunken in the ground, harbored a second instar female and her web. August 6, 1942.

Flushing, N. Y. A 4 by 4 beam had been shattered and thrust into a heap of earth. A second instar female was nesting among the shattered splinters about one foot above the ground. October 7, 1941.

Riker's Island, N. Y. In an area of approximately one quarter acre in the city dump were 35 *Latrodectus* nests, all located under very flimsy cover such as old shingles, two by fours, soap boxes, etc. The selection of such insecure nesting places was probably due to the high population in a limited area.

These spiders have been collected in their webs from April until January. They could probably be collected throughout the year should the diligent entomologist have the fortitude. However, the best collecting is done from September 1 until November 1 from the author's experience.

There are indications that there is a considerable migration of young black widows in the early fall. The site of the New York World's Fair in Flushing, immediately after the disassembly of the buildings, was found to support a number of the spiders. On October 1, 1941 a 2-acre plot on this site was selected. Each piece of rubbish on this plot was overturned and inspected for spiders. Two black widows were found, both mature females. The same procedure was carried out on October 16, when one mature and 4 immature black widows were taken in the same area. Subsequent biweekly examinations revealed the ingress of new immature spiders each time. A final inspection for the season made on November 13 revealed that no new spiders had migrated into the plot since November 1. This same area was next inspected on April 18, 1942, and no new spiders had entered since November 1. This seems to show that there is a considerable fall migration of black widow spiders, particularly immature forms. There is no apparent early spring migration.

That there is some redistribution of individuals during the summer months is apparent from the following observations. During the summer of 1942 a 12-foot length of a 12 by 12 timber was found at the site of the U. S. Steel exhibit at the World's Fair Grounds. The first examination of the lower surface of this timber revealed two mature female black widows and their webs. These were collected. Regular inspections of this same timber were repeated at 2 and 3 week intervals from July until October. Each inspection disclosed another spider and her web, until a total of eight mature spiders

Table 1.—Distribution of black widow spider in New York.

LOCATION	SEASON	YEAR	TIME SPENT COLLECTING	NO. SPIDERS
Riker's Island	August	1945	1 day	58
World's Fair Site	Fall	1941	4 months	26
World's Fair Site	Spring-Summer	1942	6 months	18
World's Fair Site	Summer	1943	4 days	5
World's Fair Site	Summer	1944	5 days	7
World's Fair Site	Summer	1945	6 days	3
Forest Hills	Summer	1942	1 day	1
Corona	Summer	1942	2 days	2
Gerritson Beach Bkn.	October	1948	1 day	1
Bay Terrace S.I.	Summer	1944	4 days	4
Bay Terrace S.I.	Summer	1945	2 days	2
Bay Terrace S.I.	Summer	1946	2 days	3
Bay Terrace S.I.	Summer	1947	1 day	1
Bay Terrace S.I.	Summer	1948	2 days	0
Randall's Island	August	1945	1 day	1
Great Kills S.I.	Summer	1947	1 day	3
Great Kills S.I.	Spring	1948	2 days	2
Total spiders found				137

had been collected from beneath this one timber. Inspections made of the same timber in the summer of 1943 indicated that the spiders were again taking advantage of this hiding place.

It therefore seems evident that the black widow spider does not establish a permanent web or nest, but that she may migrate about the countryside during the summer and fall. It is most unlikely that these migrations occur during the daylight hours. The author has never seen mature black widows balooning, or running about the ground. Always in the daytime they have been under cover with their webs. Only one instance of a balooning has been noted in the daytime, and that was done by a second instar female.

The distribution of the black widow spider throughout New York City indicates that it avoids places frequented by man, and that it prefers the more isolated areas of the city. Table 1 indicates the number of the spiders observed or collected, the place of collection, the season of year and the relative time spent in inspecting the area.

An effective method of black widow spider control was followed by the City of New York, Department of Parks, when that agency took possession of the site of the World's Fair grounds in Flushing. The fairly high black widow population found there in 1941 has been steadily reduced, and since 1945 the author has not found one individual within this area, although fairly regular inspections have been made up to the present time (February, 1949). The western half of this park area has been carefully cleaned of all rubbish, reseeded and covered with grass. As this work was done, all suitable nesting places for the spiders were eliminated, and they were forced farther and farther into the eastern part of the park. This eastern section contains little of public interest and has been temporarily abandoned pending plans for its development. In this part, however, the natural distribution of weeds and grasses has had time to function, and most of the once barren areas are now covered with vegetation. The presence of this vegetation seems to have discouraged the spiders, even though the old nesting places are still present. Perhaps a factor in this is the increase in the number of hiding places for the large nocturnal beetles which the spiders use as a staple diet: the more grass roots these beetles can burrow into, the fewer beetles will hide under the webs of the spiders. In any event, the increase of vegetation on the area has resulted in a decrease in the spider population.

In conclusion, black widow spiders have been found in many parts of New York City. Their habitat follows a rather typical pattern, the web being near the ground, under a fair sized plank or cover, and located in a barren section of flat land. The web does not constitute a permanent home, but the spiders migrate during the warm months, particularly during the early fall. They may be controlled by cleaning and planting littered and barren areas.

Red-Banded Leaf Roller Injury to Peaches and Plums

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The red-banded leaf roller, *Argyrotaenia velutinana* (Wlk.), has been reported to feed upon at least 63 different food plants although apple seems to be the preferred host. Hough (1927) recorded this insect from both peach and plum and stated that peaches were occasionally attacked, but the damage was much less severe than that occurring on apples. A review of the literature relating to this species indicates that typical injury to peaches and plums has not been described.

FIG. 1.—First-brood injury to Stanley plums.

FIG. 2.—Pupae of *Argyrotaenia velutinana* on immature drop plums.

INJURY TO PLUMS.—Leaf roller damage to Stanley plums was first observed in Ottawa County, Ohio on June 23, 1948, during a routine collection of drops in connection with plum curculio studies. This injury was quite noticeable because of the large, irregular, scarred areas on the surface of the fruit as a result of first-brood larval feeding. In most instances only the skin and the flesh just beneath the skin were eaten although some larvae constructed tunnels beneath the skin. The typical appearance of damaged plums is illustrated in figure 1. Approximately 12 per cent of the drop plums collected on June 23 and June 29 showed evidence of leaf roller feeding. From the number of pupae found on drops it appears that a large percentage of larvae pupate on or within the drop fruits, as shown in figure 2. Adult moths reared from these larvae and pupae were identified by Mr. Carl Heinrich as *Argyrotaenia velutinana* (Wlk.).

Later studies indicated that second-brood larvae caused only a slight amount of injury in comparison with that observed from first-brood larvae. The foliage in this orchard was examined casually several times in late June and July but no evidence of foliage injury was observed.

The orchard, in which leaf roller injury was observed, was originally employed for insecticidal studies with plum curculio. When leaf roller injury appeared, records of fruits injured by this species were taken separately in each of the 32 plots. These plots, consisting of four trees each, represented eight treatments of six different insecticides. Each treatment was replicated four times and the applications were begun shortly after petal-fall. Three applications were made at 10-day intervals. A summary of these preliminary observations indicated that the extent of leaf roller injury was less in plots treated with parathion, acid lead arsenate, toxaphene, and refined benzene hexachloride, whereas it was more severe in the technical benzene hexachloride and chlordane plots.

INJURY TO PEACHES.—Leaf roller injury to peaches has been noted for the past several seasons although the extent of injury has been so limited that it has been considered incidental. During 1948, several leaf roller larvae causing injury to peaches were reared and the adults were later identified as the red-banded leaf roller. Observations indicate that injury to peaches is most likely to occur where the foliage is in close contact with the fruit, since the larvae construct silken shelters between the two surfaces and feed within the protective webbing. The photograph in figure 3 shows this type of injury to a Cumberland peach. In instances where foliage is not in contact with the fruit the larvae have a preference for feeding in the depression near the stem end of nearly mature peaches. In one Elberta orchard some leaf roller larvae were observed to enter and feed within peaches which had developed a split pit condition. It is interesting to note that most of the injury to peaches was caused by second-brood larvae while this brood caused only minor injury to plums.

FIG. 3.—Second-brood leaf roller injury to Cumberland peach.

The increasing usage of benzene hexachloride or chlordane to control plum curculio on stone fruits and the ineffectiveness of these materials against red-banded leaf roller suggest the possibility of increased injury to peaches, and perhaps other stone fruits, by this pest. In all of the peach orchards where leaf roller injury was observed the grower had employed benzene hexachloride for plum curculio control. However, since these observations have been confined to a single season, there is thus far no evidence that this insect is becoming a serious problem on stone fruits in Ohio.

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Control of Cherry Fruit Flies[1]

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During the seasons of 1947 and 1948 several new insecticides were compared with the standard lead arsenate treatment recommended for cherry fruit fly control. In the tests, isolated orchards or large blocks in an orchard were used for each treatment. No check plots were used, as the flies travel long distances. Observations indicate that infested orchards tend to remain infested unless the flies are repressed by an effective control program. Information on the infestation was secured by making counts in the test orchards the year before the experiments were conducted. This method gave some information on the infestation that normally would have developed in the absence of control measures.

The emergence of the fruit flies was timed by the

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use of emergence cages and bait traps. The cloth covered emergence cages were placed over soil that was known to contain pupae of the fruit fly or was placed under infested cherry trees. The bait traps were suspended from the central portion of the trees and were charged with a 2 per cent solution of household ammonia. In the vicinity of North East, the black cherry fruit fly, *Rhagoletis fausta* O. S., emerges about a week before the cherry fruit fly, *R. cingulata* Loew. Normally the flies are present in the orchards around June 10 and if favorable weather prevails at this time the greatest number of flies will be present in the orchards for a period of 10 to 14 days.

The sprays were applied with a power sprayer, using a single nozzle orchard spray gun. All the spraying was done from the ground and from the outside of the tree. Two applications of sprays were applied to the test orchards. The spray dates were as follows: in 1947 the first application was made on June 20 and the second spray was applied June 27; in 1948 the first application was applied June 11 and the second spray was applied June 24.

Previous to the time the maggots began leaving the fruit a sample of cherries was taken from the center trees of the test plots. The cherries were counted and placed in trays which had quarter-inch galvanized hardware cloth bottoms. The trays were suspended over water and maggots leaving the fruit dropped into the water. A record was made of the number of these maggots.

The materials used in the experiments were as follows: parathion,[1] a wettable powder containing 15 per cent and 25 per cent parathion; chlordan,[2] a wettable powder containing 50 per cent chlordan; DDT,[3] a 50 per cent wettable powder; lead arsenate, an unconditioned commercial product containing 19.50 per cent metallic arsenic and 58 per cent metallic lead; in 1947 fixed copper,[4] (1.5 pounds to 100 gallons) and hydrated lime (3 pounds to 100 gallons) were added to the spray mixtures. In 1948 ferric dimethyl-dithiocarbamate[5] (2 pounds to 100 gallons) was used with parathion and chlordan and fixed copper and hydrated lime was used with lead arsenate and DDT.

A summary of the results and a list of the treatments are shown in table 1. Lead arsenate, the standard treatment for the cherry fruit fly, was included in the tests each year. The results indicate that DDT was effective for the control of the cherry fruit fly. The infested fruit ranged from 0.21 to 0.58 per cent. As may be seen in table 1, chlordan did not appear to give satisfactory control of the cherry fruit fly. The infested fruit ranged from 0.52 to 3.65 per cent. Parathion gave excellent control of the cherry fruit fly. During the 2 years that experiments were conducted no cherry fruit fly maggots were recovered from the fruit that was sprayed with parathion. The orchards (Nos. 10 and 11) in question were small plantings and had been heavily infested in previous years with cherry fruit fly.

Since cherries are used either as fresh fruit or processed, the spray residue on the harvested fruit is of considerable concern to the grower and to the processor. For the seasons of 1947 and 1948 residue determinations were made on the cherries sprayed with parathion. The parathion residues[6] were as follows: in 1947 (18 days after the last application of spray) the residue on the harvested fruit was 0.17 p.p.m.; in 1948 (14 days after the last application of spray) the residue was 0.05 p.p.m.

Table 1.—Summary of results of experiments for control of cherry fruit flies.

Orchard No.	Year	Material and amounts per 100 Gallons		Maggots per 100 Fruits
1	1947	Lead arsenate,	2 lbs.	0.29
2	1948	Lead arsenate,	2 lbs.	0.00
3	1947	DDT,	1 lb.	0.37
4	1948	DDT,	1 lb.	0.21
5	1948	DDT,	1 lb.	0.58
6	1947	Chlordan,	1 lb.	0.52
7	1947	Chlordan,	1 lb.	0.97
8	1948	Chlordan,	1 lb.	1.29
9	1948	Chlordan,	1 lb.	3.65
10	1947	Parathion,	0.45 lb.	0.00
11	1948	Parathion,	0.375 lb.	0.00

DISCUSSION AND SUMMARY.—The results of the experiments indicate that parathion is as effective as the standard lead arsenate treatment for the control of the cherry fruit fly. The parathion residue on the harvested fruit does not appear to be a problem of major importance. The residue on the fruit in 1947 was 0.17 p.p.m. and in 1948 the residue was 0.05 p.p.m. Although chlordan greatly reduced the infestation in the test orchards the control was not satisfactory. In one orchard 3.65 per cent of the fruit was infested. For canning cherries, not more than 0.5 per cent of the fruit can be infested with fruit fly maggots. Therefore, one should not consider a spray program effective for the cherry fruit fly unless 99.5 per cent of the fruit is free of maggots.

[1] American Cyanamid Co., New York, N. Y.
[2] Dow Chemical Co., Midland, Mich.
[3] Geigy Company Inc., New York, N. Y.
[4] The Sherman Williams Co., Cleveland, Ohio.
[5] *Fermate*. E. I. Du Pont de Nemours and Co., Wilmington, Del.
[6] Determined by the Analytical Research Laboratory of the American Cyanamid Co.

Tests of Insecticides to Control Red Spider Mites[1]

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Red spiders have been considered a pest of cotton many years and sulphur has been used for control with varying degrees of success. Recently the species of mites found to infest cotton in Texas was determined by McGregor (1948) as *Septanychus* sp., probably a new species. In cotton fields bordering pastures which had been dusted with organic insecticides for the control of grasshoppers, a severe infestation of this red spider developed. This infestation developed as a result of the destruction of the natural enemies by the organic insecticides and also because of favorable weather conditions for mite development. The experiments herein reported were conducted near College Station during 1948 for the purpose of comparing several insecticides for the control of red spiders.

The red spider population on cotton was determined by counting the mites on approximately 50

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Table 1.—The initial red spider adult population on cotton and per cent control on experiment 1, College Station, Texas.

Treatment	Pounds per Acre	Initial Population,[1] June 10	Per Cent Control Hours After Application				
			8	27	75	100	124
Parathion-inert (1% parathion)	9	56.3	91.0	99.8	99.1	97.4	97.1
Bis(P-chlorophenoxy) methane-inert (20%)	9.5	63.2	22.2	13.6	37.6	23.5	25.4
Sulphur	27.5	62.7	26.2	66.0	94.6	78.6	88.9

[1] Average number adults per leaf.

Table 2.—The initial red spider adult population on cotton and per cent control on experiment 2, College Station, Texas.

Treatment	Pounds per Acre	Initial Population[1] June 11	Per Cent Control Hours After Application			
			8	56	80	104
Parathion-inert (0.5% parathion)	12.4	58.4	93.7	96.9	93.0	82.6
Parathion-inert (0.25% parathion)	15.8	50.9	82.8	84.1	56.1	39.6
Sulphur	33.2	46.6	22.1	79.0	79.5	86.5

[1] Average number adults per leaf.

tagged leaves in each plat. The leaves were tagged in order that the same leaves might be examined on each date so as to eliminate variation as nearly as possible. Only one leaf per plant was tagged.

On peanut plants, the population records were made on 20 leaflets on each of 10 tagged clumps in each plat. Abbott's formula was used to calculate the percentage controls.

Experiment 1, table 1, was conducted to determine the effectiveness against red spiders of the 3 following materials: (1) 1 per cent parathion-inert, (2) sulphur and (3) 20 per cent bis (P-chlorophenoxy) methane[1]-inert. The plats were arranged in a latin square. Each plat was 6 rows wide and 100 feet long. An application of each of these materials was made on June 11 at the average rates indicated. Later, June 17, the entire experiment was dusted with sulphur by plane, at 18 pounds per acre.

Both sulphur and parathion proved effective against the mites, whereas, neotran dust proved ineffective. The application of sulphur applied by plane at the rate of 18 pounds per acre, reduced the mite population 80 per cent.

Experiment 2, table 2, was designed to determine the strength of parathion dust necessary to control red spider mites. The plats were arranged in randomized blocks, each treatment as well as each check or untreated plat was replicated 3 times. Each plat was 6 rows wide and 100 feet long. An application of each of these insecticides was made on June 12

[1] *Neotran.*

Table 3.—The initial red spider adult population on cotton and per cent control on experiment 3, College Station, Texas.

Treatment	Pounds per Acre	Initial Population[1] July 20	Per Cent Control Days After Application			
			2	3	4	6
Parathion-inert (0.5% parathion)	10	30.6	96.2	91.1	76.8	33.0
Sulphur	25	30.3	78.1	83.2	45.5	89.5
Dinitro-o-cyclohexyl phenate-inert (1.5%)	10	28.8	41.3	36.6	39.9	0.0

[1] Average number adults per leaf.

Table 4.—The initial red spider adult population on peanuts and per cent control on experiment 4, College Station, Texas.

Treatment	Pounds per Acre	Initial Population[1] August 3	Per Cent Control Hours After Application				
			24	72	120	144	168
Sulphur	25	1869	98.4	100.0	99.9	100.0	99.8
Dinitro-o-cyclohexylphenate-inert (1.5%)	10	1726	88.7	95.0	96.9	83.7	0.0

[1] Average number adults per 20 leaflets.

at the average rates indicated. Later, June 17, the entire experiment was dusted with sulphur by plane at the rate of 18 pounds per acre.

Both the 0.5 per cent parathion and the sulphur were effective in reducing the mite population while the 0.25 per cent parathion dust was ineffective. These results indicate that a dust containing at least 0.5 per cent parathion is necessary for effective control. Sulphur applied at the rate of 18 pounds per acre reduced the mite population 92 per cent.

The red spider population in the field where experiments 1 and 2 were located, increased following the applications as indicated, making a later application necessary to prevent injury. This indicates that neither of the insecticides tested possessed ovicidal qualities.

Experiment 3, table 3, was located in a field of cotton in which the mite population had increased following several applications of DDT-inert dust. The following materials were used: sulphur, 0.5 per cent parathion-inert and 1.5 per cent dinitro-o-cyclohexyl phenate-inert. The plats were arranged in randomized blocks, each 6 rows wide and 100 feet long. Each treatment as well as each check was replicated 3 times. An application of each of the above mentioned insecticides was made on July 21 at the average rates indicated. Another application of the insecticides was made on July 28; however, due to the early maturity of the cotton, the mites migrated out of the check plats, making it impossible to evaluate the results.

Both 0.5 per cent parathion dust and sulphur again gave good control while the 1.5 per cent dinitro-o-cyclohexyl phenate dust was ineffective. It will be noted that the parathion gave a quicker kill, but the population began to increase after an interval of 4 days. The mortality on the sulphur treated plats was highest on the sixth day. The poor results obtained from the dinitro-o-cyclohexyl phenate dust may have been due to the poor dusting qualities of the material which made it difficult to obtain adequate coverage of the cotton plant.

Experiment 4, table 4, located in a field of peanuts was designed to compare the effectiveness of 1.5 per cent dinitro-o-cyclohexyl phenate-inert and of sulphur when used against the spider on another host plant. Each plat was 6 rows wide and 100 feet long and each treatment was replicated 3 times. An application of the materials was made on August 4 at the average rates indicated.

Sulphur gave satisfactory control during a 7-day period while a new generation of mites developed on the plats treated with dinitro-o-cyclohexyl phenate dust, 6 days after the application was made. In this experiment, better control was obtained with dinitro-o-cyclohexyl phenate dust than in experiment 3 where it was used on cotton. This was probably due to the better distribution of that dust on peanuts than on the cotton.

SUMMARY.—Parathion dusts at a concentration of 0.5 per cent or more were effective in controlling the red spider mites. This material gave a quick kill, but did not have residual or ovicidal properties. One and one-half per cent dinitro-o-cyclohexyl phenate dust was ineffective against the mite on cotton, probably, due to the poor dusting qualities of the dust. This material gave better control of the mite on peanuts. Sulphur applied at the rate of 18 pounds per acre gave as good control and a longer residual action than any of the other materials used. Twenty per cent bis (P-chlorophenoxy) methane dust proved ineffective.

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Soil Insecticides for Control of Cutworms

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Studies were initiated in January 1948 on the effect of January versus March treatment of soil with broadcast applications of insecticides for the control of wireworms. Unfortunately, it was not possible to continue the study as such because of severe infestations of cutworms which caused most of the damage observed in early spring to seedling corn.

There was, however, a marked difference in cutworm damage in plots treated in January when compared with the damage done in the March treated plots. Consequently, the work originally planned as a study in wireworm control was continued as a study of cutworm control. This paper presents a summary of the method of soil treatment and the results obtained in the control of cutworms in two different areas of eastern North Carolina.

EXPERIMENTAL PLAN.—The work was planned to test the difference in control of wireworms obtained by soil insecticides applied in January as compared with applications made nine weeks later, in March, just prior to planting of the test crop, corn. An identical program of testing was planned for two difierent and widely separated fields in order to study the effects on the different species of wireworms infesting these fields. Field 1 was located at Wilmington (New Hanover County) about 140 miles southeast of Raleigh. Field 2 was located at Swan Quarter (Hyde County), 170 miles east of Raleigh. Field 2 was 160 miles north of field 1.

MATERIALS USED.—Four insecticidal dust formulations were used including chlordan, benzene hexachloride, DDT, and a combination dust of DDT and benzene hexachloride. The various dust formulations and the rate per acre at which they were applied are listed in table 1.

PROCEDURE.—The dust materials were either standard commercial preparations or were cut down from a concentrate base with either pyrophyllite or attapulgite. Applications were made with a power duster to soil that had not been turned after harvest of the previous crop, which in both fields was soybeans planted in rows. In both fields, the low bean stubble and the small amount of vegetation left in the field after harvest served to catch the dust probably more so than would a bare field.

In the January treatments, the soil was harrowed to a depth of 6 to 7 inches immediately after the insecticide had been applied. The field was not harrowed again until it was time to prepare the seed bed. Only one application of dust was made in the January treatment and this at about 9 weeks before time of planting.

The March treatments were handled in the same manner as the earlier treatments. In general, the plots treated in March were planted 2 to 3 weeks after the soil insecticidal treatments were made.

The test crop in both fields was corn and a locally

Table 1.—Materials used and number of corn plants per 100 feet of row.

Swan Quarter Field

Material[1]	Concentrations and lbs. Used per Acre	Number of Plants per 100 Feet of Row Count of May 11		Count of June 2	
		January Treatment	March Treatment	January Treatment	March Treatment
Benzene hexachloride, 1%	20[2]	67	100	41	74
Benzene hexachloride, 1%	40	63	99	68	77
Chlordan, 5%	40	68	95	38	77
	100	66	110	46	87
DDT, 10%	100	80	101	39	71
Benzene hexachloride, 1%—DDT 5% combination dust	20	91	110	37	86
Untreated check		67	103	33	76

Wilmington Field

Material	Lbs. per Acre		Number of Plants per 100 Feet of Row Count of April 27	
	January Treatment	March Treatment	January Treatment	March Treatment
Benzene hexachloride, 2%	10	10	19	123
Benzene hexachloride, 2%	20	20	0	109
Chlordan, 5%	20	100	1	118
	40	200	19	113
DDT, 50%	20	20	53	104
Benzene hexachloride, 0.5%—DDT 5% combination dust	20		39	
Untreated check			18	97
Benzene hexachloride 0.5%—DDT 12.5%		40		137

[1] Acknowledgement is made of the following companies who contributed materials for this experiment: Dow Chemical Co., Midland Mich.; Penn. Salt Mfg. Co., Philadelphia, Pa.; Velsicol Corp., Chicago, Ill.; and O. E. Linck and Co., Clifton, N. J.

[2] Technical grade benzene hexachloride used, concentration percentages refer to actual amount of gamma isomer in the technical grade material.

produced white field corn was used. Corn was machine-planted in the drill about 8–9 inches apart.

Plots were, for the most part, 0.2 acre in size. In the Wilmington field, plots were replicated twice for each treatment date. In the Swan Quarter test, the January treatments were made on single plots about 0.5 acre in size and the March treatments were made on 0.2 acre plots replicated four times. In each field, treatments were randomized for each treatment date but all January treated plots were located in two blocks at one end of the field and the two blocks of the March treated plots were adjacent to them.

The effect of off-flavor that the various insecticides might impart to root crops, such as potatoes, is of importance when soil insecticide applications are considered. As a check on possible off flavor, two 25-foot strips of Irish potatoes were planted in all plots of the January and March treatments at Swan Quarter. These potatoes remained in the soil until they were mature.

PLANT COUNTS.—The condition of the January treated plots of the Wilmington field in late April indicated that cutworms were doing most, if not all, of the damage to seedling corn, which at this time averaged about 4 inches high. The condition of the March treated plots in this same field was noticeably better than that of the January plots. Plant counts were made to determine the number of plants per 100 feet of row. The unit sample used in making these plant counts was 5 lineal feet of row. Enough of these unit samples were taken at random in each plot to make up at least one-tenth of the actual area of the plot. In the Wilmington test, plant counts were made on one date only but in the Swan Quarter test, two plant counts were made; the first on May 11 when corn averaged 4 to 5 inches high and the second count on June 2 when corn averaged 20 inches high.

CUTWORM DAMAGE IN JANUARY VS. MARCH TREATED PLOTS.—In the Wilmington field, the damage by cutworms to corn planted on the January treated plots was very evident. Corn in all plots of the first block of replicates of the January treatment was completely destroyed except for a few border rows. The damage was less severe in the adjoining second block of replicates of the January treatment. Both blocks of replicates of the March treatment at Wilmington appeared normal.

Cutworm damage at Swan Quarter was not as severe as at Wilmington. However, the same general condition prevailed here as at Wilmington, namely, the pronounced damage by cutworms to corn in the January treated plots as compared with damage to corn in the March treated plots.

The cutworm species involved in either field was the black cutworm, *Agrotis ypsilon* (Rott.). This species is familiar to farmers in eastern North Carolina, where its distribution in 1948 was widespread. Cold, wet weather probably retarded the growth of corn thus providing a longer period of time during

which seedlings remained in a stage attractive to cutworms.

The peak of cutworm damage occurred when corn averaged 4 inches high. In the Wilmington field the peak was noted during the last week of April and in the Swan Quarter field the peak of damage came during the second week of May.

The total number of plants recorded in the unit samples is presented in Table 1 on the basis of number of plants per 100 lineal feet of row.

The March treated plots in both fields had the greater number of plants. This increase in stand in all cases can be attributed to the lesser amount of cutworm damage in the March treatments. Soil samples taken in all the plots of the Wilmington field after treatment showed that the numbers of wireworms per sample in each of the plots did not vary significantly. Furthermore, the number of wireworms in the entire field was probably at too low a level to be used for any conclusive work on control even had the cutworms not entered into the problem. The same conditions were true in the Swan Quarter field.

EFFECT OF SOIL INSECTICIDES ON FLAVOR OF IRISH POTATO.—All plots of the Swan Quarter field had Irish potatoes planted in them. These were dug when mature. Potatoes dug from each plot were distributed to two groups of individuals for table use in their own homes. No individual knew that the potatoes had been planted in insecticide-treated soil. Each person was merely asked to accept the potatoes, use them, and report on their quality. It is realized, of course, that such a test is not very scientific but at least the reactions of two groups testing the same potatoes could be compared. No individual reported any off-flavor or undesirable qualities in any of the potatoes. This does not mean that potatoes grown in treated soils will not be off-flavor. The problem of off-flavor is not as acute in field corn as it is in Irish potatoes. Nevertheless, the use of soil insecticides cannot be generally recommended until problems arising from their use have been more completely studied.

SUMMARY.—Dust formulations of chlordan, benzene hexachloride, DDT, and a combination dust of DDT and benzene hexachloride were used in two fields 160 miles apart. Originally set up as a test for wireworm control, this work became a study of cutworm control because of a severe intestation of cutworms, *Agrotis ypsilon* (Rott.), in both fields. Dust applications were made by a power duster to the soil surface. One part of the field was treated in January, at 9 weeks ahead of corn planting, and the other part of the field was treated in March, at 2 weeks before corn planting. In both fields, cutworm damage was more severe in the earlier treated part of the field.

Irish potatoes grown in the Swan Quarter field, when cooked, showed no off-flavor due to any of the insecticidal treatments, according to the reports from two separate groups of tasters who had not been told of the treatments.

Mass Rearing of Drosophila

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The following method of rearing is an adaptation of the one by Hodson & Chaing (1948) using fresh cake yeast as larval food. It is clean, easily set up, and has very little objectionable odor.

Fold three paper towels twice (12 thicknesses) and place in the bottom of a gallon mayonnaise jar. Treat with 20 drops of propyleneglycol as a mold deterrent. Mix two cakes of yeast with 5.0 ml. of water and place in the middle of a dry twice folded (4 thicknesses) paper towel on which 4 drops of propyleneglycol have been placed. On top of the yeast place a 9.0 cm. square of dry paper toweling wet with one drop of propyleneglycol. Place this whole assembly on the paper in the jar and wet the paper with 85 ml. of water. A screened metal lid with a double cheesecloth is used as a cover which allows any toxic gas to escape.

Anaesthetize 75 to 100 3-day-old *Drosophila melanogaster* (35 to 50 females in a random sample) with carbon dioxide, transfer to the prepared jar with an aspirator and hold in an incubator at 24° C. Egg laying starts within 24 hours and pupation occurs in 4 days, the adults emerging in 10 days Treat with CO_2 at peak emergence and transfer the adult flies to a clean gallon jar in which a sugar-milk cake (Hoskins & Caldwell 1947) and a cotton stoppered water vial have been placed; cover with cheesecloth lid and hold for testing or for stock.

The transfer and anaesthetization is accomplished by placing the jar on its side and blowing CO_2 through the cloth lid for about 10 seconds until the flies begin to drop. Being on the side of the jar the flies are easily picked up by an aspirator or a spoon. 75 to 100 adults produce 1000 to 1500 progeny. After pupation and before emergence a piece of sugar and milk cake (2 parts powdered whole milk, 1 part sugar and 0.6 parts water, mixed, beaten and spread on waxed paper to a thickness of 3 mm.) is placed in the jar as food for the emerging adults.

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A New Bait Trap Collection Record for *Rhagoletis completa*[1]

D. M. BENJAMIN and A. C. HODSON

Two species of the walnut husk fly, *Rhagoletis completa* Cress, and *R. suavis* (lw.)[2] were collected in bait traps in Minnesota in 1941 during apple maggot bait trap investigations.[3] The traps used

[1] Paper No. 2481 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

[2] Determined by A. Stone, Washington, D. C.

[3] Benjamin, D. M. and A. C. Hodson, 1942. The apple maggot problem again. Minn. Hort. 70: 54–55.

Table 1.—Tabulation of *Rhagoletis* flies collected in bait traps in walnut plantation in Minnesota in 1941.

	R. completa		*R. suavis*		*R. pomonella*	
	female	male	female	male	female	male
Total catch by sexes	119	45	132	56	3	1
Per cent catch by sexes	72.6	27.4	70.2	29.8	75.0	25.0
Total catch by species	164		188		4	
Per cent catch by species	46.1		52.8		1.1	

during this preliminary survey were one quart oil cans filled with a 2 per cent glycine 3 per cent sodium-hydroxide solution. Three traps were hung on the lower branches of Thomas and Ohio Black Walnut trees in a small plantation at the University of Minnesota Fruit Breeding Farm at Excelsior, Minnesota on June 20, 1941. The traps were refilled with water on July 16, 1941, after having become completely dry. The first walnut husk flies were observed in the traps on August 9, and all of the flies were removed from the traps on August 24. Table 1, a tabulation of the proportions of flies caught, indicates that 46.1 per cent were *R. completa* and 52.8 per cent *R. suavis*. The remaining 1.1 per cent were *R. pomonella* migrants from a near-by apple orchard

This collection record is of especial interest because it represents an extension of the range of *Rhagoletis completa* east of the ninety-fifth meridian and northeast from Lincoln, Nebraska, into Minnesota. Also, it is the second published record of *R. completa* and *R. suavis* being collected in the same nut orchard. The first collection of these two species in the same orchard was made at Manhattan, Kansas, in 1932 where *R. completa* was collected in a ratio of 50:1 of *R. suavis*.[1]

[1] Boyce, A. M. 1934. Bionomics of the walnut husk fly, *Rhagoletis completa* Cress. Hilgardia 8(11): 363–579.

The DDT Content of Milk from a Cow Sprayed with DDT

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Howell *et al.* (1947) have shown that DDT appears in the milk from cows sprayed with either xylene emulsions or suspensions of DDT. Samples of milk taken at regular intervals showed a maximum of 33.6 p.p.m. of DDT in 20 days after daily applications of 2 quarts of 5-per cent DDT, and its presence was demonstrated in the milk over periods of several months after the last spray application. Much less DDT (0.2 to 2.5 p.p.m.) was found in milk from cows sprayed every 14 days with wettable-powder suspensions or emulsions containing 0.25 per cent of DDT. It has been pointed out by Carter *et al.* (1949) that after five sprayings with 0.5 per cent DDT suspensions made with commercially formulated wettable DDT from 0.1 to 2.0 p.p.m., with an average of approximately 0.5 p.p.m., of DDT appeared in the milk over a period of about 5 months. Six sprayings with wettable-powder suspension containing 0.25 per cent of DDT resulted in 0.1 to 1.5 p.p.m., with an average of approximately 0.3 p.p.m., in the milk over the same period. These experiments were conducted at commercial dairies, and the intervals between sprayings were governed by the recurrence of an annoying abundance of horn flies, *Siphona irritans* (L.). Milking was done by machine, and all precautions were taken to prevent contamination of the milk with DDT from outside sources.

Further data have been obtained on the amounts of DDT found in milk produced primarily for home consumption from a herd sprayed by a commercial operator with DDT wettable-powder suspension. An Iowa farm herd of 21 Shorthorns, including cows and calves, was sprayed once by means of a high-powered sprayer with DDT at a concentration of 4 pounds per 100 gallons. The cattle were sprayed over the entire body to the point of saturation and considerable run-off.

One of the cows in the herd was used as a source of milk for the owner. Milking was done by hand without particular precautions to prevent contamination of the milk with DDT from outside sources. A check sample of milk before spraying was not obtained, but so far as is known the cow had not been sprayed previously with DDT and had not received forage containing DDT residues. Samples of milk were taken from the cow beginning the second day after spraying and analyzed for their DDT content by the colorimetric method recommended by Schechter *et al.* (1947). The date of spraying was July 17, 1948. The amounts of DDT found in samples of the milk taken at intervals thereafter are shown below.

Date of Sampling	P.p.m. of DDT
July 19	3.0
22	1.8
26	.9
Aug. 2	1.4
9	.5
24	.4

The results indicate that after one spraying of a dairy cow with DDT, amounts averaging 1.3 p.p.m. of DDT appeared in the milk over a period of approximately 5 weeks.

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Toxicity of DDT and Parathion Dusts to the Citrus Blackfly

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The citrus blackfly, *Aleurocanthus woglumi* Ashby, one of the major citrus pests of the world, has become established in Mexico. The great citrus-producing areas in the northern part of that country as well as in the United States are now threatened. Studies by Plummer & Shaw (1947) and subsequent field use in many parts of Mexico have demonstrated the value of cube in light-medium emulsive oil for the control of this insect. More recently, unpublished field data from Cuernavaca, Morelos, Mexico, have shown the high toxicity to the immature stages of the citrus blackfly of sprays containing 2 or 3 pounds of 15 per cent parathion wettable powder in water to make 100 gallons. More extensive field tests in Los Mochis, Sinaloa, Mexico, by Woglum *et al.* (1949) have shown that 1 pound of a 25-per

Table 1.—Numbers of living larvae and pupae of the citrus blackfly found on leaves 19 days after they were dusted with DDT or parathion.

Insecticide	Larval Instar			Pupae
	First	Second	Third	
DDT:				
20 per cent	0	0	55	4154
10 per cent	10	33	410	6423
Parathion:				
2 per cent	74	0	0	10
1 per cent	111	0	0	1
Control	1008	736	2122	8124

cent parathion wettable powder plus 1 quart of commercial summer spreader and water to make 100 gallons is highly toxic. The present note indicates the potential value of parathion when applied as a dust.

Thirty sour lime trees, 12 to 15 feet high, in a large grove in Ticuman, Morelos, were selected, and six well-separated trees were assigned at random to each treatment. In the early morning of November 26, 1948, six trees were heavily dusted with different strengths of DDT or parathion using approximately 7 pounds per tree. The dusts were applied with a large power duster and all safety precautions were taken. Six trees served as untreated controls. Mean temperatures after treatment were close to 66° F. Only 0.06 inch of rain was recorded (Dec. 9).

Samples of 50 leaves were picked at random from each tree 19 days after the dusting and the living blackflies counted under stereoscopic microscopes. These data are summarized in table 1.

The presence of living first-instar larvae on the treated leaves indicates that dusts containing 10 per cent of DDT or 1 or 2 per cent of parathion did not kill all the eggs and the larvae upon hatching. The toxicity of the two parathion dusts to second- and third-instar larvae and to pupae was excellent. Further studies may show that even lower concentrations of parathion dust will kill these stages of the citrus blackfly.

These preliminary data indicate the possibility of improving present methods of controlling the citrus blackfly. Parathion is a very toxic insecticide, and every safety precaution should be followed in handling or applying it in any form.

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Lindane

A common name for essentially pure gamma isomer of benzene hexachloride

The word "lindane" has been selected as the *common name* for the gamma isomer of benzene hexachloride of a purity of not less than 99 per cent.

Information concerning the name and the approval and acceptability of its use as a coined, common name for this specific definition is filed with the Trade-Mark Division of the U. S. Patent Office, Department of Commerce, to preempt use of the name "lindane" as a trade-mark. Notice of the selection of the common name and the definition are being forwarded to officials and agencies in other countries.

The Chairman of the Committee on Insecticide Terminology of the American Association of Economic Entomologists advises the Committee approves the use of the common name as defined, and authorizes announcement to this effect. The Insecticide Division of the Production and Marketing Administration of the U. S. Department of Agriculture and the Secretary-Treasurer of the Association of Economic Poisons Control Officials advise that "lindane" is acceptable as a common name as defined and may be used on labels of insecticides. (For method of use in ingredient statements for labels see illustration in the attachment.) The Committee on Therapeutic Agents and Appliances of the American Veterinary Medical Association advises that the common name and the definition are acceptable. The Chief of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture; the Bureau of Medicine and Surgery, Department of the Navy; the Office of Chief of Engineers, Department of the Army; Preventive Medicine Branch, Office of the Surgeon General, Department of the Air Force; and the Food and Drug Administration, Federal Security Agency, advise the common name as defined is acceptable and will be used by their agencies. The Editor of *Chemical Abstracts* advises that the name would be acceptable from a chemical nomenclature point of view.—7-12-49.

S. A. Rohwer
Chairman, Interdepartmental Committee on Pest Control.

The National Malaria Service of Brazil has just begun the publication of "Revista Brasileira de Malariologia." Volume 1, No. 1, January 1949, contains seven articles which deal with various aspects of the malaria problem especially the habits, distribution and importance as vectors of various anopheline mosquitoes.—F. C. Bishopp.

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The Entomologist and the International Health Program

The international health program in which the United States is playing a leading role has as its objective the improvement of health throughout the world. The underlying motives are several: to lift the great burden of suffering that exists today; to improve the productiveness of the world's manpower as the basis for a sound general economy; to protect our own shores and to build a more stable human foundation for peace. This means speeding the economic development in all countries. As economic development depends on manpower and manpower in turn depends on nutrition and health, the key to this great endeavor is the World Health Organization and, in this hemisphere, the Pan American Sanitary Bureau, which is being integrated as the regional office of the World Health Organization. Additionally, the United States is working toward the same end through bi-lateral programs designed to give help in the field of health to individual nations in which we have special interests such as in Greece, the Philippines, China and the Latin American countries.

Nationally, our defense against introduction of diseases from abroad may no longer be passive. In any event, attack is always the best defense. Epidemic and endemic diseases must be attacked on a global basis. The attack must not stop at control, but must proceed to eradication in order to eliminate foci of infection in one country as a protection for all others. This is a prominent feature of the program of the World Health Organization.

It is at once apparent that the immediate pressing health problems, in regard to which rapid improvement can be obtained involve the control and eradication on a wide basis of many arthropod-borne diseases. I need only refer to malaria (the greatest offender against health); mosquito borne filariasis, dengue and yellow fever; tick and louse borne relapsing fever; flea borne plague; louse and flea borne typhus; and fly borne trachoma and dysentery. The list can be greatly extended to include diseases attacking perhaps half the population of the world.

The increasing speed of international travel lends an urgency to entomological research. There appears to have been little inter-continental travel of insects, excepting *Aëdes aegypti*, during the days of slow international travel. There is some reason to believe that the airplane has already caused the development of a trend in insect travel and we have taken cognizance of this. The Public Health Service has established the system of entomological surveillance around the principal airports of ingress, so that if a new species is implanted its early discovery will permit economic eradication.

A fleet of jet planes has already crossed the Atlantic and the day of the rocket plane is in view, a day when Cairo and Washington will be as close together as are Buda and Pest. Results of this shrinkage are already apparent, for diseases of short incubation and short infective periods are on the move. Japanese B. Encephalitis has left its home in Southeast Asia and recently produced a severe epidemic in Guam. Before further shrinkage occurs, means must be discovered for preventing the international travel of disease-bearing insects and of the diseases they convey. At present we depend upon disinsectization of carriers and upon surveillance of travelers—not the strongest of reeds upon which to lean. A surer method might be based upon a greater knowledge of the habits of insects.

A mere inspection of the problem highlights the essential role of the entomologist. It remains only to examine the na-

ture of the problem which he is called upon to solve.

The amount and intensity of insect-borne diseases are determined by the relationship between the habits of insects, which are usually more or less fixed, and the habits of human beings, which are diverse and changeable. Obviously, a fundamental attack would be through developing a new habit of man, a habit inimical to the insect.

In eradicating a disease there is a chain which must be broken somewhere. It may be broken through control of animals, such as the rat in bubonic plague; by botanical means, such as vegetation control in mosquito infested waters; by adoption of a human habit, such as the boiling of garbage prior to feeding pigs as a means of control of trichinosis; but most often by the control of some insect vector.

The entomologist is primarily concerned with the insect and its place in the train of events. He may call upon the knowledge of other specialists, for the answer to his problem may lie in taking advantage of some characteristic of environment or of the habits of a living organism resident therein. Team work is necessary and constant readiness to adopt new methods. For example, let us consider the case of bubonic plague. Traditionally, the weak link has been the rat; now, with DDT, the weak link may be the flea. Certainly it is easier to dust this powder on the runways, and let the rat disinsectize himself, than it is to eliminate the rat.

I know of no way whereby an insect may be induced to change its habits, but this process I have observed among human beings and we should take advantage of it. Imagine the truly remarkable reduction of disease, particularly in the tropics, which will result when human beings throughout the world develop, as a habit of living, the process of regularly painting DDT upon the walls of their houses and out buildings. The resulting comfort, through freedom from insect annoyance, may very well induce the development of this procedure as a new habit. When the habit becomes established, malaria can maintain itself in the world in only a few small localized foci and these can be removed through other means.

The entomologist must find the weak spot in the life cycle or habits of the insect vector, which indicate the point of attack. Any such study must have a dependable and accurate classification as a starting point, hence the entomologist must be a taxonomist. But, if he is not now, he must become a student of natural history. The most effective work of the entomologist begins where that of the taxonomist ends.

It is the knowledge of the habits of the anophelines which makes it possible to use DDT effectively. Residual house spraying was indicated because of the knowledge that most anophelines rest on nearby walls before or after feeding. Hertig has shown that sand-fly control can be effected by painting the rims of doors and windows or by spraying DDT at the orifices of breeding areas or daytime rocky crevices where phlebotomus roosts.

Concurrently there is need for speeding-up the study of insect habits, and the habits of the local population where insect-borne diseases are now endemically entrenched. In our own United States the reason why DDT is so effective against *Anopheles quadrimaculatus* is obvious. This mosquito bites indoors during the night and then roosts on the nearest wall to commence digesting its blood meal. The presence there of a poison capable of entering an insect through its feet can hardly fail to produce the desired result. In those countries where *Anopheles minimus* is the malaria vector, DDT residual spraying is effective too, though the reason is not so obvious. *A. minimus* does not roost in plain sight on walls but it does so roost for a brief period prior to feeding and it also crawls into the thatch roof; thereby the spraying method is also effective. If all anophelines roosted nearby only just prior to feeding and if this characteristic had been unobserved, then the use of DDT residual spray might have been a discovery still in the future.

In the Philippine Islands, where *Anopheles minimus flavirostris* is the vector, considerable doubt was expressed of the value of residual house spraying because this mosquito does not roost in houses in the day-time and may not so roost prior to or following its feeding. A large scale experiment is now underway to test the effectiveness of the method. Should the test prove negative, other economic means will have to be utilized to eradicate this mosquito, possibly through a determination of its other roosting habits. It may be that DDT is not being put in the proper

place. With this or any other mosquito species it may be established that a more concentrated dose of the insecticide, in a few properly selected small areas, may prove entirely satisfactory.

If a disease is to be eradicated, we recognize the indispensability of the physician; if the disease has an animal reservoir, we are beginning to recognize the indispensability of the mammalogist; if there is particular vegetation among which the animal or insect lives, feeds and breeds, we come to realize the necessity for the botanist. Thus, we realize the important part that is being played, and the increasing part which must be played, by the entomologist in discovering the habits of these vectors and in devising means of using this knowledge in the eradication of insect-borne diseases. This is well exemplified in the new problem of yellow fever.

Yellow fever, as a disease of man, has for long been under control with its reservoir safely confined to the jungle. There is now an urgent necessity that this jungle reservoir be eradicated. The disease has been eradicated from urban centers through control of *Aëdes aegypti*. Dr. Soper has just given us a vivid description of *Aëdes aegypti* eradication and emphasized the necessity for this measure on a continental basis. On a global basis there is a further consideration. Yellow fever remains as a jungle disease principally in monkeys and, in South America at least, is transmitted from monkey to monkey by at least one mosquito which breeds in the water collections in tree holes often high in the branches of the forest jungle. Eradication of such a mosquito, based on present knowledge, would be a gigantic undertaking. However, if the disease is not eradicated, what are the chances of forever keeping it out of that great subcontinent, the Indian peninsula? India and Pakistan represent a large area with a population of about 400,000,000 people, probably 350,000,000 of whom live with both the urban vector, *Aëdes aegypti*, and the monkey, an animal sacred to a large proportion of the inhabitants. If yellow fever should enter this subcontinent, its eradication, or even that palliative known as control, would be a tremendous task. Until the disease were eradicated, the whole area would be a focus of infection, dangerous to the entire world. Its eradication would not only be expensive but peculiarly difficult, as the disease would be an epizootic as well as an epidemic.

Will yellow fever enter India? I believe this is inevitable if it remains in other parts of the world. Consider for a moment the history of the travels of yellow fever. When small sailing ships carried open water-butts, they bred the mosquito continuously. There is a record of one vessel which experienced a smoldering epidemic over a period of 53 days, between South America and Africa. Although steamboats did not permit the breeding of this mosquito, their more rapid travel carried infected persons greater and greater distances. This hazard did not abate until ports were freed of the disease. But now explorers, geologists, conservationists, and others are entering the jungle in increasing numbers, are coming out to take airplanes to distant points, and are arriving at their destinations well within the yellow fever incubation period. The only certain method now in use of preventing infection is anti-yellow fever inoculation. But can we be sure all such persons are inoculated? Can we hope to give preventive inoculations to everyone in the world south of 30° north latitude? What else in these days of accelerating speeds will surely prevent infection of India and the consequent hazard to the rest of the world?

There is but one hopeful approach and the entomologist better than any other is equipped to provide it. It is essential that the habits of forest vectors be so completely studied that from this knowledge may come an economical method for the eradication of jungle yellow fever.

This problem offers an opportunity as well as a challenge to the entomologist. It is an example of his value to the international health program. His future place will be self-determined by his success in finding and capitalizing upon the weakest link in the chain of arthropod-borne disease. Developing habits of life among people which habits stop the transmission of diseases is the ultimate solution of the problem of controlling communicable diseases.

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